

The WHAT'S NEW magazine

SEPTEMBER 1988

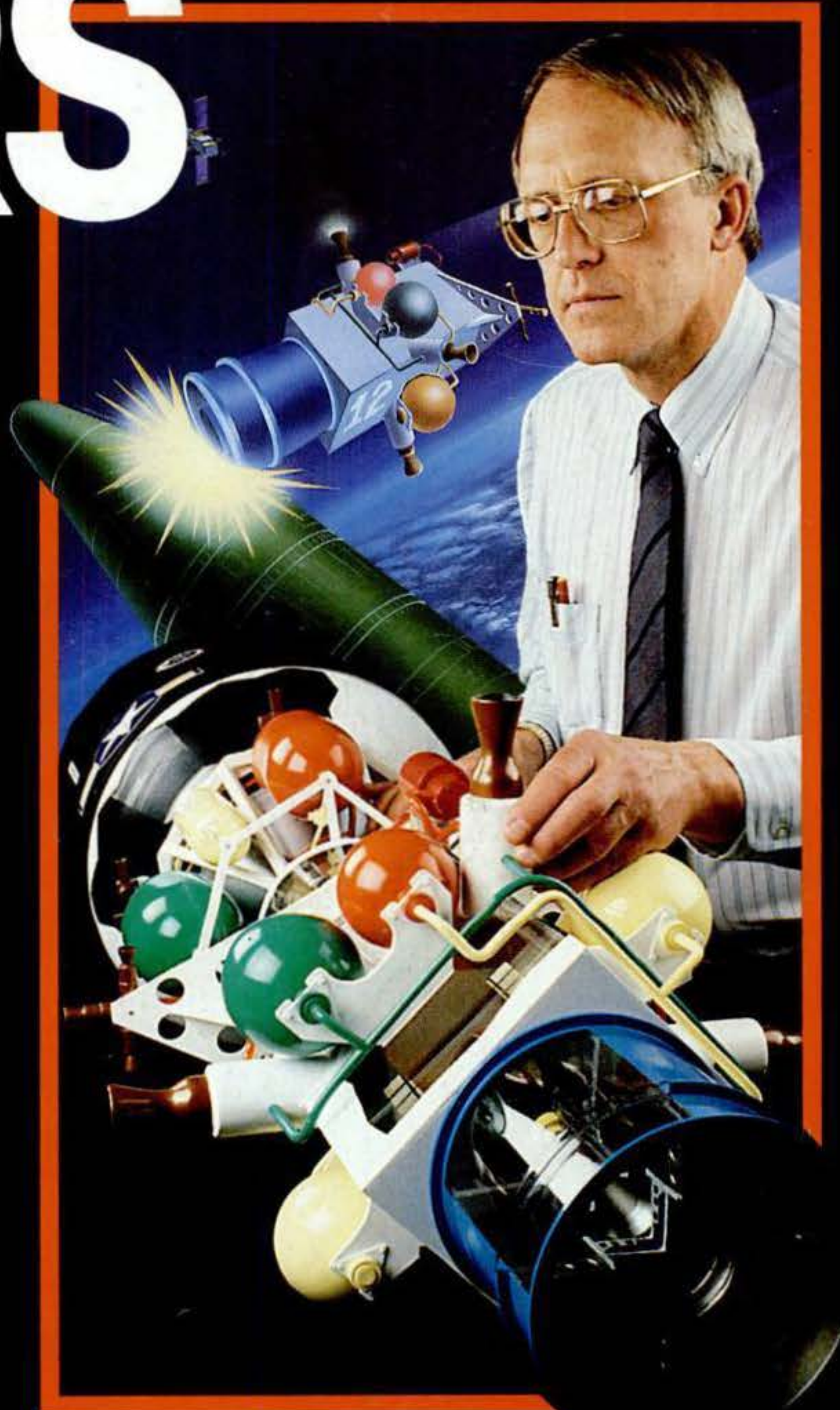
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Popular Science®

BIG SPECIAL SECTION • How to build a sunspace • Buyer's guide to wood and metal kits • Pro's installation tips • Get smart about glazing • Essential accessories

MISSILE KILLERS

This device is designed to destroy attacking missiles in space. Proponents of the "Star Wars" program say a network of these satellite-launched interceptors can provide a significant deterrent to nuclear attack. A legion of critics counters that the program is too expensive and too technologically complex to be workable. The exclusive report inside gives the details.





SURGEON GENERAL'S WARNING: Smoking
By Pregnant Women May Result in Fetal
Injury, Premature Birth, And Low Birth Weight.

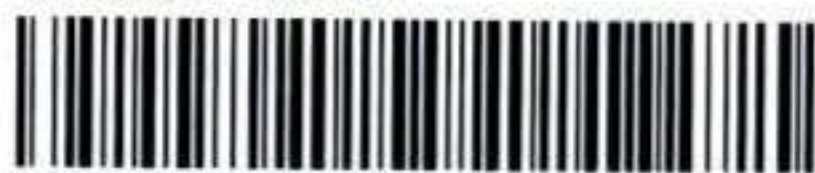
10 mg "tar," 0.7 mg nicotine av.
per cigarette, FTC Report Feb. '85

Marlboro Lights

The spirit of Marlboro in a low tar cigarette.



This One



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Missile killers

"Smart rocks" carry no explosives. But if they only graze a missile's highly stressed skin, it's enough. The missile explodes, and undetonated nuclear warheads tumble back to Earth. **Page 46**

Sunspace!

How do you keep today's hottest home improvement from getting too hot—or cold? Our special section answers the questions you might have about the wide choice of sunspace kits and accessories available. **Page 61**



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The odd couple

The challenger: a 90-foot mono-hull with an enormous sail area and an unusual winged hull. The U.S. defender: a 60-foot catamaran. And the America's Cup will never be the same again. **Page 54**

6 quick coupes

Small, fast, nimble: Sports coupes from Ford, Nissan, Toyota, Mazda, Dodge, and Chevrolet are put through their paces to find who's the hottest of the hot. **Page 32**





Larry finds a refuge.

They all agreed they'd keep him for just one night. But by morning, he'd purred in the mother's lap, played with the father's worn-out sock and been named Larry by the daughter.

Finally, he'd found himself a permanent refuge from all he'd known before.

The house. Window after window made Larry's new home seem more spacious than it was. Let the light flood in. Kept the coziness from slipping out.

One of them interested Larry and became his favorite spot. All of them did something special for the owners of the house.

The windows. Each of the windows ... from the small one that let light into the bathroom to the big bay that Larry liked best ... was *The Intelligent Window*®. A kind of window made with a remarkable glass, *Sungate*® coated low-E glass from PPG.

Sungate coated glass lowers heating bills in winter by keeping inside heat in. And lowers cooling bills in summer by keeping outside heat out.

Its special coating makes *Sungate* coated glass up to 70% more effective at insulating than uncoated glass.

The purrs. Truth be told, even though PPG *Sungate* coated glass helps save Larry's owners money, Larry doesn't care. He's just glad the bad times are over as he lies purring in the window, taking in the view.

For more information on how windows made with *Sungate* coated glass from PPG can add to the warmth, beauty and openness of your home, send for your *free* brochure. Or, call 1-800-2-GET-PPG to find out

who in your area sells windows and doors with *Sungate* coated glass.



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Readers Talk Back

Stealth signature

Your article "Finally: Stealth!" in the July issue was great! Anti-radar measures might mean a return to acoustic listening devices used for detecting enemy aircraft. But unlike the big ears of World War II, a modern super ear could use a powerful digital signal processor to pull a known acoustic signature from beneath a high-noise floor.

Charles H. Small
Associate Editor, EDN
Newton, Mass.

Your "unofficial" information about the power plants on the B-2 stealth bomber is just a little off. General Electric engines for the B-1B are F101-GE-102 turbofans each with 30,780 pounds of thrust with afterburners. Total thrust: 123,120 pounds. That's a far cry from your reported 68,000 pounds for the B-2. The next generation of F101s will be stronger and able to produce more thrust without engaging any afterburners, therefore giving a longer range.

Daniel L. Musgrove
Tacoma, Wash.

So the stealth bomber is finally coming out of the closet. It looks like a real Darth Vader GT! In my opinion Harvard's professor William Kaufmann is right when he says that there is no rational mission for stealth. Just think of how many schools and hospitals could be built with the \$400 million-plus that each bomber will cost. I count at least 40. This sneaky stuff is pure waste, and I'm sick of paying for it.

Terry J. Du Bose
Austin, Texas

Work is going on at the Department of Defense on acoustic recognition of aircraft and on suppressing aircraft acoustic signatures, including the B-2's. One point: You have to record a signature to recognize it. It's questionable whether the Soviets would get the chance.

The B-2 bomber reportedly has four non-afterburner-equipped F-101 turbofans. In this configuration the F-101 produces 17,000 pounds of thrust

($4 \times 17,000 = 68,000$). The B-1B has afterburners on its F-101s, which give a lot more thrust.—Steven Ashley

No hidden cost

Your June article "3-D TV" mentioned a \$2,800 price for the Toshiba 3-D camcorder, but it was not clear whether this price included the black-box 3-D adapter, viewing goggles, and other required equipment, such as a monitor capable of handling a high-definition signal. If these are not included, then the investment would be more like \$5,000. I appreciate the article's wide coverage, and I'm sure you share my disappointment that the "Moonlighting"-Coca-Cola 3-D splash had to be cancelled due to the writers' strike.

Raymond W. Smith
Warner Robins, Ga.

The list price includes the 3-D adapter and a pair of goggles. Because it's not Super-VHS, any television works.—John Free

Microchip ranch

The June article "Why Is It Raining Indoors?" brings to mind the famous last word on this matter:

An inventive young man from Bordeaux

Built an air-conditioned chateau.
Due to technical blunders,
The dining room thunders,
And the bathrooms incessantly snow.

G. R. Johnson
Victoria, B.C., Canada

Your article illustrates that "smart" houses are on the increase. But beyond simplifying our lives, what we're really doing is putting computers in our homes—as well as video cameras for security and microphones for voice command—that can see and hear everything we do and say. And of course there would be a modem on the computer to monitor who's in the house when we're away. Everyone was so scared by George Orwell's book *1984*, in which the government could see and hear everything. If these "super-houses" become the trend, we will have set up a similar system for our government and even have paid for it ourselves.

Doug Cimperman,
Belleville, Ill.

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There's one mini-van that stands apart from the crowd with its distinctive aerodynamic look—the Ford Aerostar. It offers optional touches of luxury and convenience, from headphone jacks and heating/cooling fan controls for rear-seat passengers, to an overhead console trip computer.

Deluxe Comfort. Step easily into Aerostar—and

carry up to seven. Or pop out the rear seats—and take on 139 cu. ft. of cargo. Loads of living room! **Eddie Bauer Style.** Choose from sporty XL or XLT Aerostar—or the stylish Eddie Bauer (shown below). It comes with dual Captain's Chairs and seat-bed in back*. Or optional Quad Captain's Chairs. Also, two-tone paint. (Fold-away mirrors shown not available on early '89 models. See dealer for details.) **High Powered.** A multi-port Electronic Fuel Injected 3.0L V-6 comes standard, delivers a spirited 145 horsepower. So powerful, Aerostar can tow up to

In a class by itself. The '89 Ford Aerostar.





4800 lbs. when properly equipped.**

Aerostar's advanced design makes it easy to handle, garage and park.

6-Year/60,000-Mile Powertrain Warranty. Covers major powertrain components for 6 years/60,000 miles, whichever comes first. Restrictions and deductible apply. Also, participating dealers back their customer-paid work with a free Lifetime Service Guarantee, good for as long as you own your vehicle. Ask to see these limited warranties when you visit your Ford Dealer.

Ford. Best-Built American Trucks—Eight Years Running. Based on an average of owner-reported problems in a series of surveys of '81-'88 models designed and built in North America. At Ford, "Quality is Job 1."

*Seat bed standard on Eddie Bauer model and optional on XL.

**Towing rating is reduced by passenger and cargo weight in towing vehicle.

Have you driven a Ford... lately?



Buckle up—together we can save lives.

Tool tales

In June "What's New Tools" you ran a picture of a supposedly new Gripping Driver. This may be a new tool, but it's not a new idea. I've had a similar screwdriver with the split shaft wedges for at least 20 years. The only difference I can see is that the sleeve is metal on my model rather than nylon.

Warren G. Seitzinger, Merrillville, Ind.

I just wanted you to know that I have two screwdrivers that are just like the one in the Gripping Driver photo. I purchased them sometime in the early 1950s while working in the electrical department of Bethlehem Steel in Hoboken, N.J. What's new about that?

John J. Leggio, North Bergen, N.J.

Restrained praises

I was pleased to see the July article "Coming: CD recorder" on Tandy's THOR CD recorder, but I think you've exaggerated its capabilities. First, 550 megabytes of data is not "equal to a whopping 15,000 floppy diskettes." Even if you use low-density floppies with a capacity of 360 kilobytes, the number is closer to 1,500. With high-density floppies the number is less than 500. Second, I don't think it's time to say "Goodbye conventional hard-disk drives." The speed and capacity of hard-disk drives continue to increase, and their cost continues to decrease. Soon hard-disk drives with hundreds of megabytes of capacity may become commonplace.

Bob Nishi, Santa Ynez, Calif.

Squelching the squeak

July's "Car-Care Quiz" came just in the nick of time. I have a 1981 Ford Granada that squeaked every time I touched the steering. I mentioned it to my local dealer, and after three grease jobs I thought it would disappear. It didn't. Then I read the problem Moans and Groans and went to work on my car. I removed the "bone dry" bellows fittings, packed them with a lube, and the squeak disappeared!

Harry Burke, Titusville, Pa.

Availability: remote

After reading "High-Tech Products For Your Home" [April], I wrote to Feiss Industries to get information about its Remcon remote control for a ceiling fan. The company informed me that the remote control is only available to dealers and works only with

Murray Feiss fans or other fans with a removable switch-box housing.

Robert Shirley, Canton, Ohio

In the mood for metric

One small criticism of your otherwise great publication: Why use only non-metric units of measurement? It should be easy to convert every measurement into metric units and display it in parentheses next to the English unit. This should only add about 0.39 inch (1 centimeter) to the length of an article, and it might help us become metric literate.

Eric Lee, North Shore, Calif.

The piece Metric Again? that appeared in July's "What's News" column uses an incorrect term for converting from English to metric units. The term is metrication, not metrification.

R. E. Meyer, P.E.
Certified Advanced
Metrication Specialist
Pacifica, Calif.

No fan of danger

I laud reader Lane's efforts in June's "Wordless Workshop"—he's built a small-scale paint booth. However, the window fan does not meet the National Electric Code for use around explosive or flammable materials: i.e., glue and paint. As minute as the possibilities may be, he has created a potentially explosive situation if the gas-air ratio were to meet the right proportion. This may sound like nit-picking, but where children and fire are concerned, we can't be too careful.

Eldridge L. Fancher, Cincinnati, Ohio

Found: Escort part

The letter in May's "RTB" column stating that the exhaust manifold heat actuator for '81 and '82 Ford Escorts is unavailable is incorrect. I recently purchased one for \$12 plus tax. The Ford part number as of October 1986 is E1FZ-9D612-B. To purchase any diaphragm device from a junkyard is just asking for trouble.

Kenneth Munger, Jasper, Texas

Corrections: American Honda Motor Co. provided an incorrect price for its outboard motor Four-Stroke pictured in July's "What's New Recreation." The price is \$1,979.

In "No Strings Attached" [July], the price given for Universal Security Instruments' Hear 'N There wireless speaker system was \$45. The actual retail price is \$80 to \$99. **P.S.**

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Americans At Their Best.

Science Newsfront

By ARTHUR FISHER



Sweaty Manny

One of the most complex and sophisticated computer-controlled movable robots ever designed, as seen in the photos above, is being built at Battelle's Pacific Northwest Laboratories in Richland, Wash. "Manny," for robotic mannequin, is so humanlike that it even sweats.

"In its final form," says David W.

Bennett of Battelle's Applied Physics Center, "the mannequin will physically resemble the human body in size and limb and trunk geometry. It will be capable of simulating complex body movements and poses, breathing, body and skin temperature, sweating...."

Why have a sweaty robot? Manny is being built for the U.S. Army's Dugway Proving Ground in Dugway, Utah, about 85 miles southwest of Salt Lake



Battelle's new robot, Manny, is designed to simulate human motions and functions—even sweating.

City. It will be used to test protective clothing in simulated conditions that are hazardous—maybe even hellish—for humans.

"Manny will test the effectiveness of clothing used to protect people from chemicals, temperature extremes, and other hostile environments," says Bennett. It could find a job, not just with the military, but also with industries that must develop and test products

Continued

BEL TECHNOLOGY DETECTS NEW Ka BAND (PHOTO RADAR)

Don't Be Left Defenseless. Drive With BEL VECTOR 3 Radar Detector.

 Ka Band is the new police radar frequency now in use. And only the new BEL radar detectors are able to detect Ka Band.

Facts You Should Know

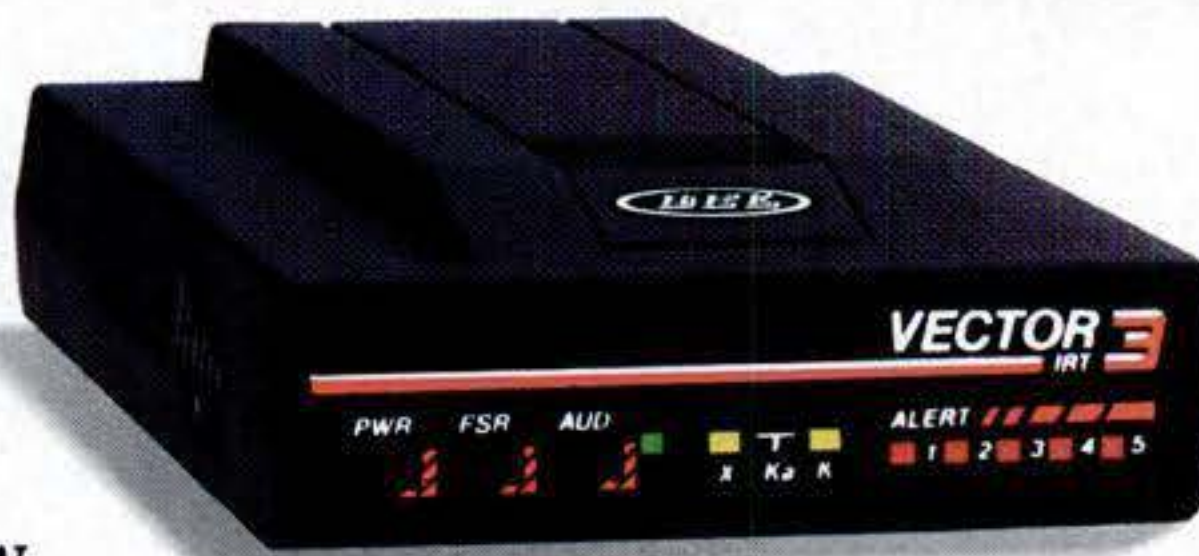
The Federal Communications Commission has approved Ka Band for police radar use. And now, many localities in the U.S. and Canada are using Ka Band Photo Radar. But the use of Ka Band isn't limited to picture-taking radar equipment. Standard police radar units can also utilize Ka Band. And as more states quietly introduce Ka Band radar, drivers with only X and K Band radar detectors are left defenseless. Unless they're driving with the new VECTOR 3.



VECTOR 3 comes with everything you see here.

No Quick Fix

Your existing X/K Band radar detector can't be adapted to receive Ka Band signals. For the level of protection VECTOR 3 offers you have to look to the technology leader. The first in the industry with 3 Band technology: BEL-TRONICS.



VECTOR 3 measures only 4.66" L x 3.19" W x 1.095" H.

Greater Detection Range

VECTOR 3 detects X, K, and Ka Band radar. And that's significant. But there's more, it's called Image Rejection Technology (IRT®). BEL engineers have incorporated this technology into VECTOR 3. The result is incredible performance and greater detection range of all police radar.

VECTOR 3 Knows

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VECTOR 3 was designed to make early detection of police radar easy and convenient. You can own the new VECTOR 3 today for only \$279.95. Just call toll-free to order. UPS delivery is FREE. Or ask about our Federal Express overnight service. If not completely satisfied, simply return the unit within 30 days for a full refund (factory direct only). VECTOR 3 comes with a full 1 year warranty on parts and service.



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VECTOR 3 Remote

The advanced technology and performance advantage of the VECTOR 3 is also available in a remote design for only \$299.95. VECTOR 3 Remote utilizes a compact antenna for easy "under-the-hood" installation. And a very small control panel for discreet positioning in any vehicle.



Compact control panel
is only 3.5" L x 2.5" W x .67" H.



The mock space shuttle Pathfinder is mated to a real external fuel tank before installation at a space museum.

for use in a variety of hazardous situations: firefighting and working in nuclear reactors and toxic waste disposals come to mind.

Manny has about 40 articulated joints that accommodate motion and enable clothing under test to be stressed. Attached to its back is a support arm that helps the mannequin simulate walking, bending, squatting, and crawling in a prone position. Hydraulic devices located in each joint power the robot's movements.

Manny's skeleton is formed of tubes and pivots, visible in the close-up photo of the arm and shoulder. The skeleton is covered (in the final version) with a flexible plastic skin.

And sweating? Perspiration is simulated by injecting water at several skin surface sites through an array of narrow tubes. Breathing—yes, Manny breathes too—is simulated by expansion and contraction of the chest and by injection of moist air at the nose and mouth to simulate lung inhalation and expiration.

Battelle engineers expect Manny to be fully operational late this year.

Space junk

Earth-orbiting spacecraft and satellites may be in more peril from particles of space debris no larger than thumbtacks than from metal objects the size of a kitchen sink, according to a University of Colorado professor studying the problem of space debris.

Robert Culp, associate director of

the Colorado Center for Astrodynamics, says there are now several hundred thousand bits of space debris in Earth orbit, ranging in size from paint chips to small marbles. They are especially hazardous because they are too small to be tracked by conventional radar. There are some 7,000 objects longer than 10 centimeters that are being monitored by the North American Air Defense Command. But even tiny particles can cause severe damage.

"These objects are traveling at seven kilometers per second," Culp explains. "In a typical collision in space, a one-centimeter piece of aluminum crashing into another object releases about the same amount of energy as the explosion of a standard military hand grenade."

Stacked shuttle

The spectacular exhibit being installed in the photo above consists of a real space shuttle external fuel tank mated to a simulated orbiter called "Pathfinder." The display was donated by NASA's Marshall Space Flight Center to the Space and Rocket Center, a state-operated museum located in Huntsville, Ala. Pathfinder preceded the orbiter Enterprise in tests conducted at Marshall and Kennedy Space Center.

The new Space Shuttle Park exhibit is dedicated to the crew of *Challenger*. It was engineered by Martin Marietta Aerospace, Teledyne Brown Engineer-

ing, and the Marshall Center's Science and Engineering Directorate.

Pluto observed

For the first time, astronomers have made a direct observation of Pluto's atmosphere. A team led by Dr. James Elliot of Massachusetts Institute of Technology's Earth, Atmospheric, and Planetary Science Department used the occasion of an occultation, or temporary disappearance, of a dim star as the strange planet passed between the star and Earth.

The astronomers used a 36-inch telescope aboard NASA Ames Research Center's famed Kuiper Airborne Observatory, from which the rings of Uranus were discovered in 1977. The observation was made at an altitude of 41,000 feet, as the aircraft was flying about 500 miles south of Pago Pago in the South Pacific.

The MIT team watched as Pluto occulted a faint twelfth-magnitude star and recorded changes in the light intensity of the star as it passed near, and then behind, the planet. The visible light signal gradually declined as it approached Pluto's disc, a clear indication that an atmosphere clinging to Pluto's surface was filtering the starlight.

Previous indirect studies of Pluto, based mainly on temperature measurements, had signaled the presence of a substantial atmosphere consisting of methane. Information about the physical characteristics and extent of

Continued

VANTAGE

ULTRA LIGHTS

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A syrupy oil extracted from an African plant related to myrrh could provide a repellent against disease-carrying pests such as this dog tick.

the atmosphere will emerge from analysis of the Kuiper occultation data.

Mouth lightning

Have you heard the one about wintergreen candy? If you chew some—say Wint-O-Green or Pep-O-Mint Life Savers—in a very dark room and open your mouth, bluish flashes will be seen coming from between your teeth. The (dark) parlor trick has been well known to confectionary cognoscenti—and chemists—for decades. It's an example of the phenomenon called triboluminescence (from the Greek *tribein*, meaning to rub), first reported by Francis Bacon almost four centuries ago, in which certain materials emit light when rubbed, crushed, or broken. But until now, science has only been able to speculate about the exact mechanism that would account for the particular color of the light.

Now chemists have been able to confirm and refine a 50-year-old theory of wintergreen flashes, a theory that involves the formation of areas of positive and negative charges built up on opposite sides of the cracks formed in the crushed material. Electron discharges triggered by the voltage difference bombard nitrogen molecules in the air, which emit blue-white light. Some of this light is reabsorbed by nearby wintergreen flavor molecules, which in turn respond by emitting blue-green light.

At a meeting of the Third Chemical Congress of North America held last June in Toronto, Dr. Linda M.

Sweeting of Towson State University in Baltimore, Md., said that she and her colleagues "have measured the exact wavelengths emitted by wintergreen candies, a feat that became possible only with the recent development of very sensitive detectors." The wavelengths coincided precisely with those predicted by theory.

Tick repellent

The creature in the photo above is an American dog tick, one species in an unwholesome breed of blood-sucking parasites that are capable of transmit-



This new superconducting coil was fabricated at Argonne Laboratory.

ting serious diseases to humans and animals. The dog tick carries Rocky Mountain spotted fever, which can be fatal if not treated early, and which is prevalent over much of the country, not just the Rockies. The deer tick is responsible for the alarming spread of Lyme disease, which would be receiving more attention as a major public health problem if not for AIDS.

Now entomologists at the U.S. Agricultural Research Service in Beltsville, Md., have found that oil from an African plant closely related to myrrh (of Biblical fame) contains chemicals that repel these and other ticks, and could be used in animal tick collars and repellents for humans.

The plant is *Commiphora erythraea*. "In Africa, its oil is rubbed on cattle to repel ticks and insects and soothe cuts, bruises, and scabies," says Dr. John F. Carroll. "If we could identify and purify the oil's active ingredients, they may have potential as natural repellents or toxins for ticks."

Chemical analysis along those lines is being carried out in cooperation with the Tropical Pesticides Research Institute of Tanzania, Africa.

Cool coil

Ceramists at Argonne National Laboratory, the country's lead research center for superconductivity applications, have fabricated the coil of superconducting wire seen in the photo at the bottom of the page. It is made from one of the most promising of the new high-temperature superconductors, yttrium-barium-copper oxide, which loses all resistance to the passage of electrical current at about minus 290 degrees F. The coil was made by extruding a wire of the ceramic material and then shaping it before it was fired. The promise of superconducting magnets, motors, and generators depends on the ability to make wire that can be wound in coils.

Pipe down!

Shakespeare wrote that some men could not abide the sound of bagpipes. Now physicians Robert Hartenstein and Stephen Brittain, writing in *Archives of Otolaryngology*, say that sustained sound levels at a piper's ear can reach 115 decibels, meaning that a practitioner of the ancient Scottish art could easily exceed federal noise-exposure maximums "with steady, dedicated practice." Piper's payback: hearing damage. Remedy: earplugs. The good doctors don't prescribe any relief for the audience. **P 5**

Get Into Hot Water. *Instantly.*

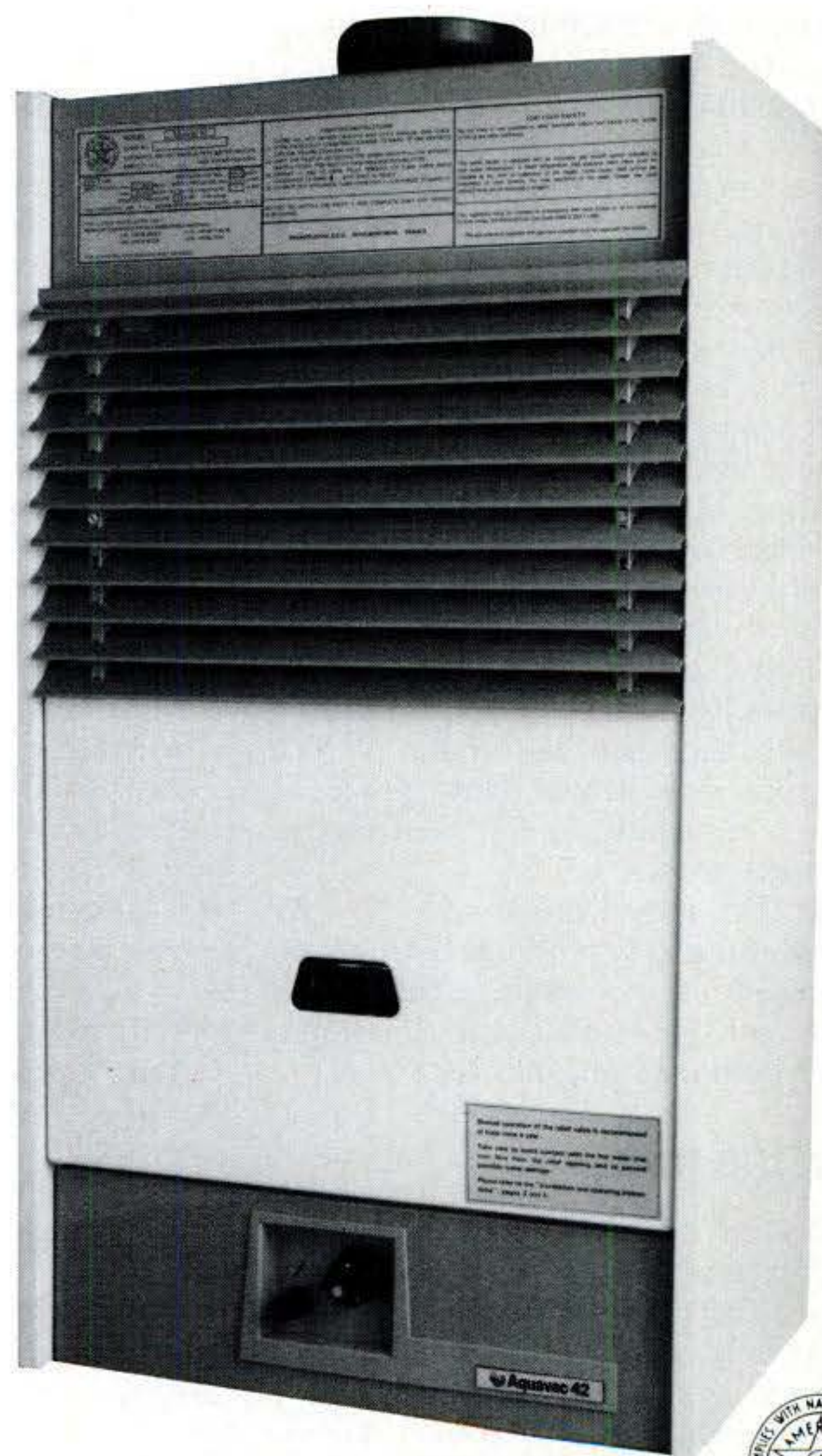
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Forget leaky tanks. Unlike storage water heaters that run out of hot water and eventually leak, the Aquavac SD-42 is tankless. Its ultra-efficient heat exchanger heats only the water you need – and only when you need it.

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The Aquavac SD-42 instantaneous gas water heater is available in either natural gas or propane gas models. Its applications are limited only by one's imagination. Millions of satisfied customers throughout the world now use the Aquavac.



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Energy Q & A

By JAN F. KREIDER

Smart 'stats for heat pumps

In a recent column [May] a reader asked about a do-it-yourself thermostat for a heat pump that would keep resistance heaters from coming on during winter morning warm-up periods. Resistance heaters often turn on because the heat pump is least effective at this coldest time of the day. Several manufacturers wrote to tell us what's available.

Honeywell's T8300 unit gradually raises the thermostat temperature over two hours instead of setting it 10 or 15 degrees higher all at once. This allows the heat pump to do more of the warming up than the resistance heat. Impac Products of Asheville, N.C., and Knoxville, Tenn., offers a line of heat-pump setback thermostats with reduced recovery rates for both residences and commercial buildings.

The Harper-Wyman Co. of Hinsdale, Ill., offers a particularly smart device that measures the morning recovery rate of interior temperature and determines whether the compressor alone can heat the building to its set point by a preselected time. If not, resistance heat is called upon. In Canada, Valera Electronics of Ottawa, Ont., produces setback thermostats for heat-pump-equipped homes.

This list is not exhaustive by any means. More new products of this type are becoming available as microelectronic controls infiltrate the home heating and cooling market.

Pick the pump

My friend has an all-electric home that he heats with a heat pump and a perimeter finned-radiator loop connected to his electric water heater. He contends that he gets the hot water free since the water heater is operating anyway. I think the heat pump is a more efficient converter of electricity to heat. Who is right?

Donald L. White, Louisville, Ky.

You are right for the following reason: There is no free heat. All that the water heating system does is convert units of electricity into units of heat, which are then conveyed inside for heating. Heat pumps, on the other hand, produce a greater heating effect than just the conversion of electricity into an equal amount of heat. The heat pump

extracts heat from the cold outdoor air, raises this heat's temperature to a useful level, and delivers it to the interior space. Heat pumps do have the disadvantage that their output depends on the outdoor temperature. As the temperature drops into the teens, resistance heat (the type of heat used in your friend's water heater) must be used to help provide the required heat on a cold day. But in your climate a heat pump is an effective way of using electricity to heat your home.

Staying in hot water

I live in a ranch-style house built on a slab foundation. Two nonadjacent bathrooms are at the far end of the house nearly 100 feet from the water heater. Several gallons of hot water are wasted en route to either bathroom. Also, the hot water remaining in the pipe cools and this heat is lost. Is there a solution to this doubly wasteful problem?

Patrick Beatty M.D., Phoenix, Ariz.

There are no solutions that save both water and energy. Of course, one would start with a well-insulated hot water system to slow the cool-down rate to the minimum possible level. It's possible to save the water you now waste by installing a small fractional horsepower pump to circulate water to the two remote bathrooms and back again. A return line would need to be added to your piping. This approach ensures hot water at all times, thereby avoiding water waste—an important consideration in your desert environment. The small pump can be controlled by a thermostat placed in the return pipe so the pump runs only when needed. This approach increases heat loss from the pipe since the piping is always hot and there is more of it, but insulation can control this problem.

Infiltration, not insulation

I plan on building a home soon in Wisconsin and would like your opinion on Du Pont's Tyvek product. Does it take the place of Styrofoam plastic foam on the outside of a wall, or is it better to use both materials?

Tom Keleny, Madison, Wis.

Tyvek is an infiltration barrier that is wrapped around the exterior of the

structural and insulation system in a home before the siding is installed. As such, it can effectively block the leakage of cold air into a building in winter or the loss of cool air from a building in summer (this is a smaller problem than the former). It is not insulation, nor is it a vapor barrier. In your climate you must include both of these in addition to Tyvek.

Mobile-home overheat

I have a friend who lives in a 20-year-old mobile home that overheats in the summer: The ceiling becomes quite hot. Short of tearing down the ceiling and adding insulation, what can be done to reduce this overheating? What about ventilation louvers and a fan?

H. Valente, South Attleboro, Mass.

A ventilation fan will do wonders for this situation. Instead of the air temperature above the roof being 120 to 140 degrees F, it will be closer to the actual outdoor temperature. Cooler air near the roof will markedly improve the comfort in this mobile home in summer. Some mobile home dwellers install wind turbines to alleviate this problem, but fans will work better. Contact a local heating and cooling contractor for recommendations on fan size and louver area.

Ducting the draft

I have a typical Cape Cod home that is heated with fuel oil and forced air. The upstairs has a finished room with a heat supply duct but no return. As a result, the cold air comes down the stairway as an uncomfortable draft. If I were to put a return duct upstairs, would that remedy the problem?

Robert Dow, Trenton, N.J.

If the upstairs room is the only source of cool air, then the return duct will help alleviate the problem. Cold air is heavier than warm air and flows downhill. It's important that the return duct be placed properly to capture as much cool air as possible. A local heating contractor can advise you.

Jan F. Kreider is a consulting engineer specializing in the design and economic analysis of energy-conservation systems. He is the author of several books on solar technology and a lecturer at the University of Colorado. Every other month he answers selected questions from readers about energy conservation or home heating and cooling. Send yours to Energy Questions, POPULAR SCIENCE, 380 Madison Ave., New York, N.Y. 10017. Queries can't be answered by mail.

Mitsubishi duo



By DAN McCOSH

WHILE driving Mitsubishi's new Galant on the winding cow paths that pass for roads in the center of the island of Hawaii, it took an unusually hard stab at the brakes or a tricky corner to provoke any sensation from the suspension.

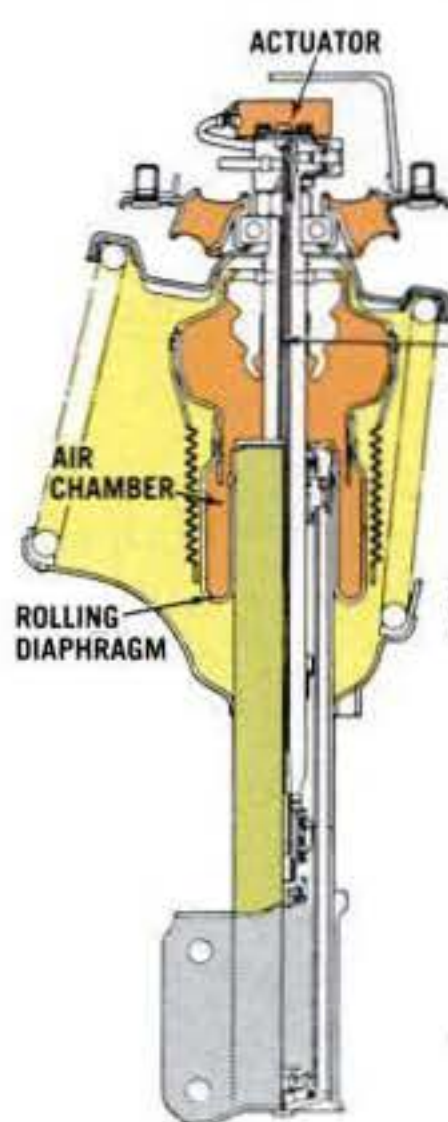
I was expecting more of a show since both the spring rates and shock valving were constantly altering as the car's speed and cornering load changed; but the smooth ride was testimony to the refinement of what is likely the most sophisticated electronically controlled suspension system in a current production car. With this new suspension, three new engines, two new models (Galant and the smaller Mirage), a joint-venture plant with Chrysler Corp. starting up, and yet more new cars coming later in the year, Mitsubishi is making a serious effort at having an impact in the United States.

The basic hardware of the suspension system is composed of MacPherson struts up front, with a twisting-beam axle at the rear. The electronic twist comes with the active suspension package. Separate air springs are incorporated at the top of the struts, along with variable-rate shock valves. A set of seven sensors feeds information about vehicle speed, turning velocity, and braking to a central computer, which responds by sending out orders to pump up a sagging corner or tighten a hopping wheel. The response rate of the air system is about one-tenth of a second, quick but not instantaneous.

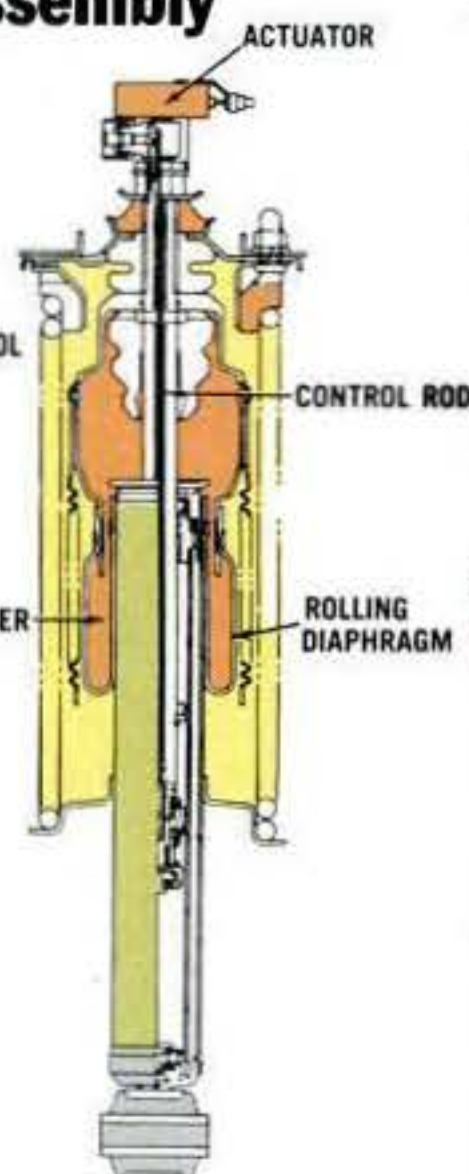
The Galant is also the showplace for a new two-liter 16-valve four-cylinder engine (see cutaway). The 16-valve-engine theme continues in the turbo-charged version of the Mirage, a 94-



Front strut assembly

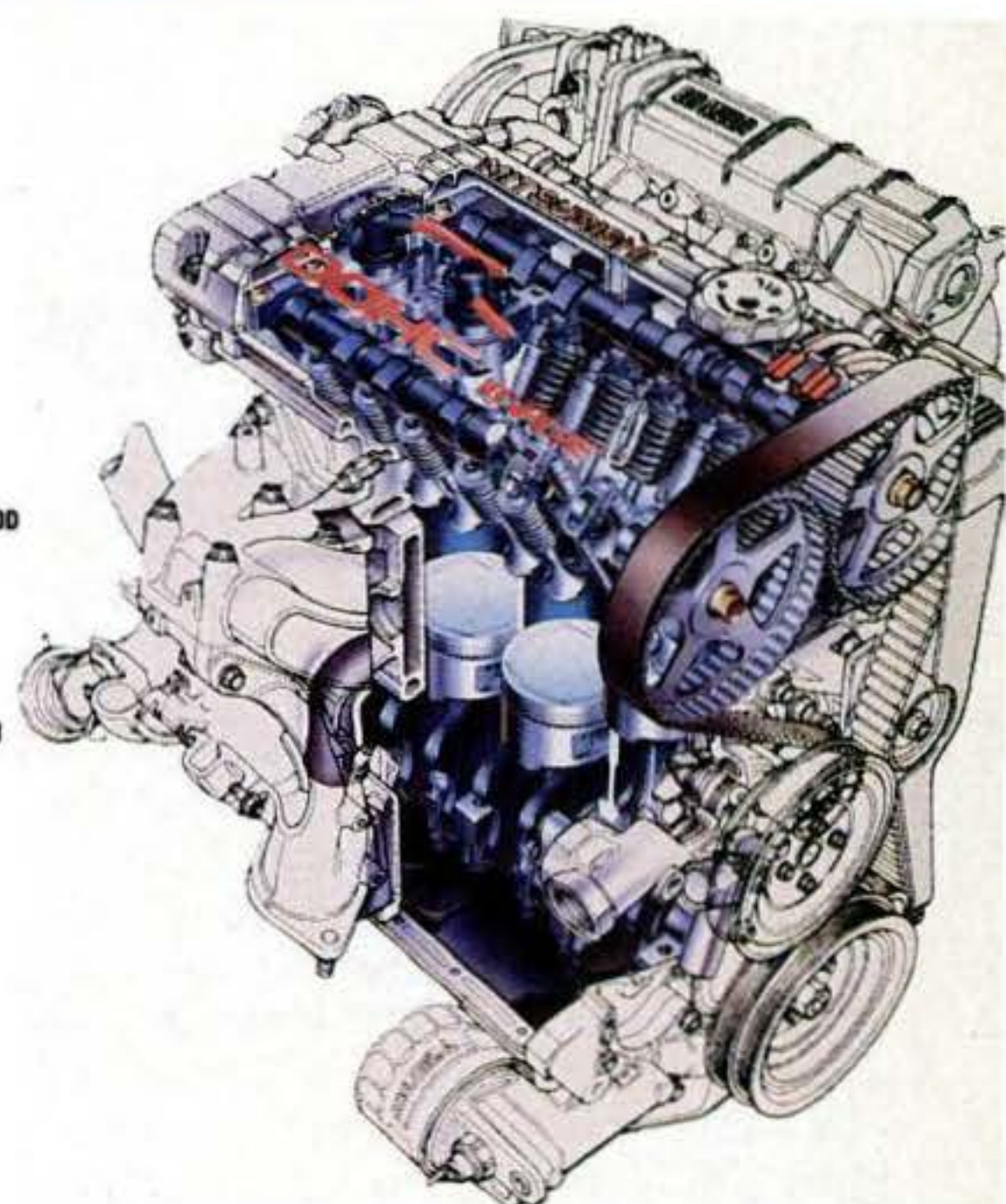


Rear shock-absorber assembly



Air-suspension actuator, controlled by the on-board computer, raises and lowers pressure of air chamber, located inside coil spring, according to road and handling characteristics.

inch-wheelbase subcompact also sold by Dodge as the Colt. The 1.6-liter turbo engine produces 135 horsepower. In its base form the Mirage engine develops 81 hp out of 1.5 liters.

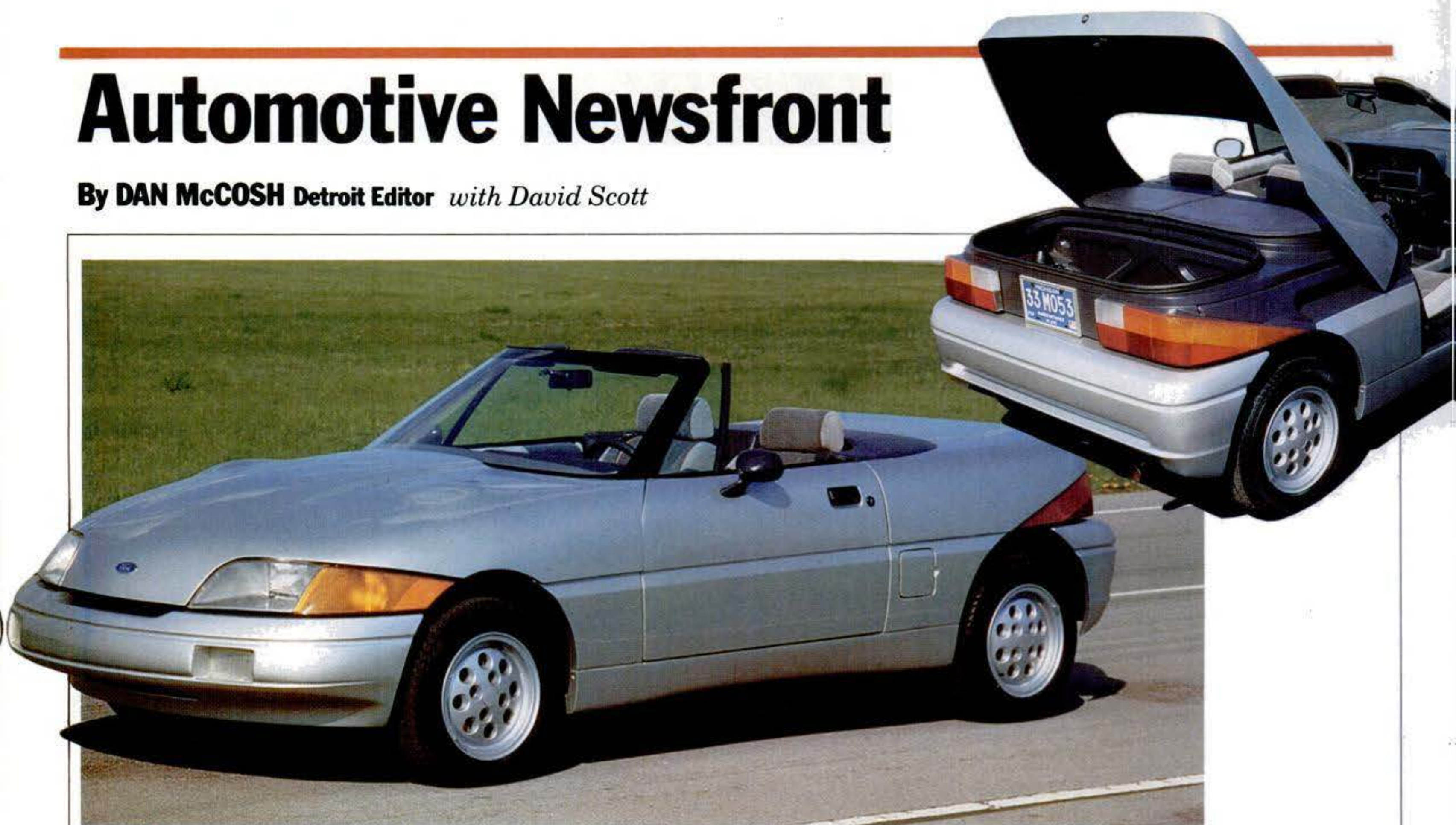


Galant's two-liter engine produces 135 hp at 6,000 rpm. Roller-cam follower in the four-valve dual-overhead-cam head reduces friction; shake is damped by counterrotating balance shafts.

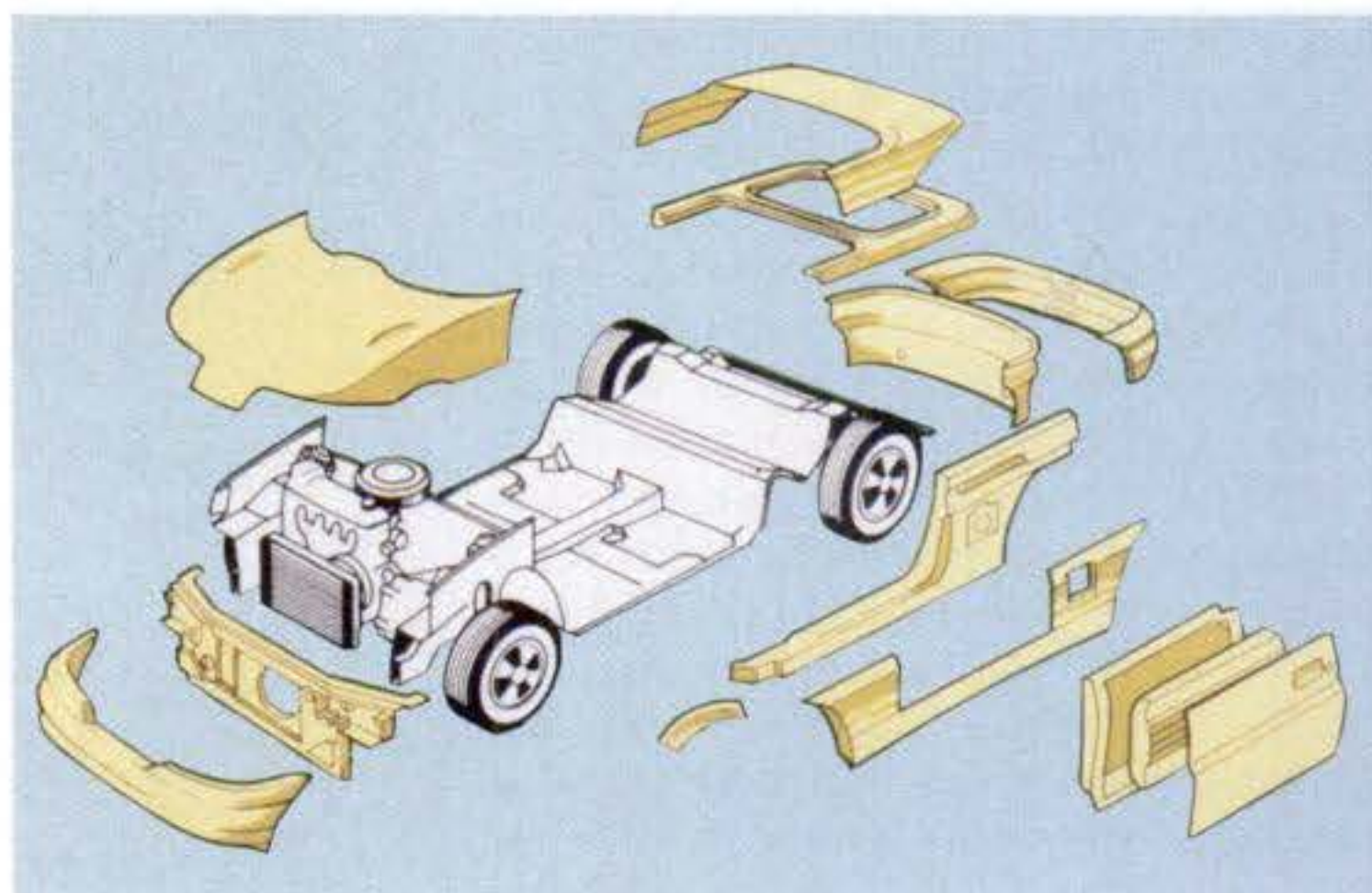
Like the Galant, the Mirage adopts the twisting-beam rear suspension. The turbo package adds rear disc brakes and stiffer springs to accommodate the added horsepower. **P 5**

Automotive Newsfront

By **DAN McCOSH** Detroit Editor with David Scott



Ford's LIV is the latest attempt to use high-strength composites to manufacture an all-plastic car. Unlike most glass-fiber cars that use a metal chassis, the LIV molds the floorpan, suspension mounts, hood and other key elements from high-strength reinforced plastics. The exploded view (right) reveals how few basic pieces are needed to complete the car, compared with the hundreds of individually assembled parts in a conventionally constructed automobile.



Plastic sportster

Futuristic concept cars usually work better posing on a display turntable than they do when you actually try to *drive* them. That is why I was surprised by the solid "thunk" of the door as I got into Ford's latest advanced-concept "LIV" (for low-investment vehicle) at the company's Dearborn, Mich., proving ground recently.

A fast couple of laps around the handling track left me with the impression of a quick, able, well-balanced sports car combining the personality of an old MG with the grip of a modern performance car. Most of the LIV's underpinnings were taken from Ford of Europe's Fiesta GT, including its 1.6-liter engine and five-speed transmission—proven components that accounted for part of the solid feel.

But there's another big reason for my surprise: The car I drove was assembled from large-scale molded plastic sections at Ford's advanced research division. And, unlike the Corvette or the ill-fated Fiero, molded

composite structures carry its major structural loads too. The result is a car that is built from one-fifth the number of pieces that are used in conventional construction.

Because plastic molds are some 60 percent cheaper than metal-stamping machinery, Ford hopes the process can dramatically reduce its production costs along with the retail price. The plastic structure also lent itself to some unusual design elements. A rear deck section incorporating the tops of the rear fenders lifts to reveal a trunk compartment that looks like a big Tupperware container.

To date, Ford has generally trailed behind both General Motors and Chrysler in the use of composite structures. But the LIV program shows that this may be changing as Ford studies the low-volume specialty car

business, which lends itself to low-cost plastic production techniques.

Italian breadboxes

The so-called "one box" design dominated the show cars at this year's Turin auto show. An example was the Asgard, a six-passenger high-speed Audi-based limousine by Ital Design.

Even more weird was the Bertone Genesis, a vanlike five-passenger design exercise powered by a 500-horsepower V12 expected to give it performance comparable with the Lamborghini Countach.

Definitely the haute couture event in the world of body design, the Turin show often brings to light the furthest-out designs in the world. Looks like the breadbox look may be with us for a while.

Continued

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Gene J. Stroner,
Vice President, Sears Automotive

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Shelby's screamers

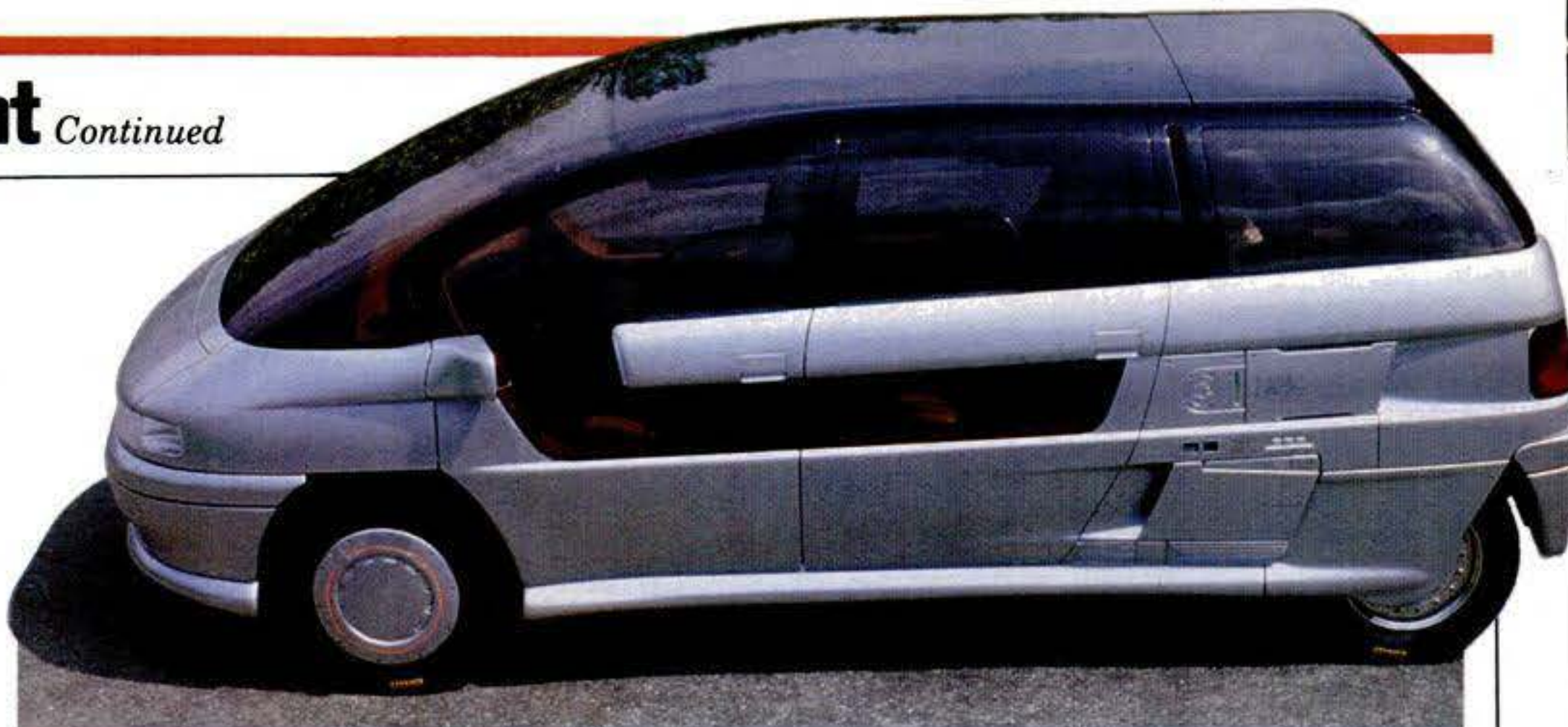
The first production application of a variable-nozzle turbocharger [cover story, May] will be a specially prepared Dodge CSX Shadow, built by Carroll Shelby's California-based performance group.

"It gets off the line like a V8," says Shelby, who has been producing low-volume, low-priced performance specials based on Dodge products for several years. The variable-nozzle turbocharger is billed as a cure for turbo lag and features a set of movable internal vanes that increases exhaust flow to the turbocharger as the throttle is depressed.

Another Shelby project underway, due to be offered in the late 1989 model year, is a Dakota pickup truck with a 3.8-liter Chrysler V8 power plant. The first V8 mini-truck to hit the market, it will include a special performance suspension package.

Adaptive suspension

Air springs, widely fitted to buses for a cushy ride, are being used by Lancia in an "adaptive" car suspension system that keeps the body level under all road and load conditions. Adaptive suspension hasn't quite the jolt-free performance of the active type (where hydraulic jacks for each wheel replace passive springs ["No-Springs, No-Shocks Suspension," July '86]), but it's far more practical in both cost and energy requirements. That's because pneumatics can combine spring and ride height functions, unlike the un-



The Asgard combines the looks of a toaster and a breadbox with an Audi chassis.

compressible oil used in a purely hydraulic system.

The Italian car maker's design uses a low-pressure air bag that supports body weight at each wheel, combined with a telescopic hydraulic shock absorber to dampen road shocks.

Heads-up is here

GM's Pontiac Grand Prix and Nissan's 240SX (see car test, this issue) will have heads-up display instrument panels in the 1989 model year. The systems vertically project a brightly lit digital speedometer reading onto the windshield, from which it is reflected to the driver's eye as an illuminated number that appears to float over the hood of the car.

Inspired by equipment developed for fighter aircraft, the automotive HUDs allow a driver to check his speed—and later, other instrumentation—without taking his eyes off the road. Early experiments attempted to focus the numbers in the distance as aircraft systems do, but engineers

found that placing the numbers too far in front hurt depth perception—test drivers began running into walls.

Exclusively 4WD

Pontiac's restyled 6000 STE will be strictly four-wheel drive in 1989. The STE package uses a center differential to produce a full-time system that doesn't have to be disconnected, even when driving on hard pavement.

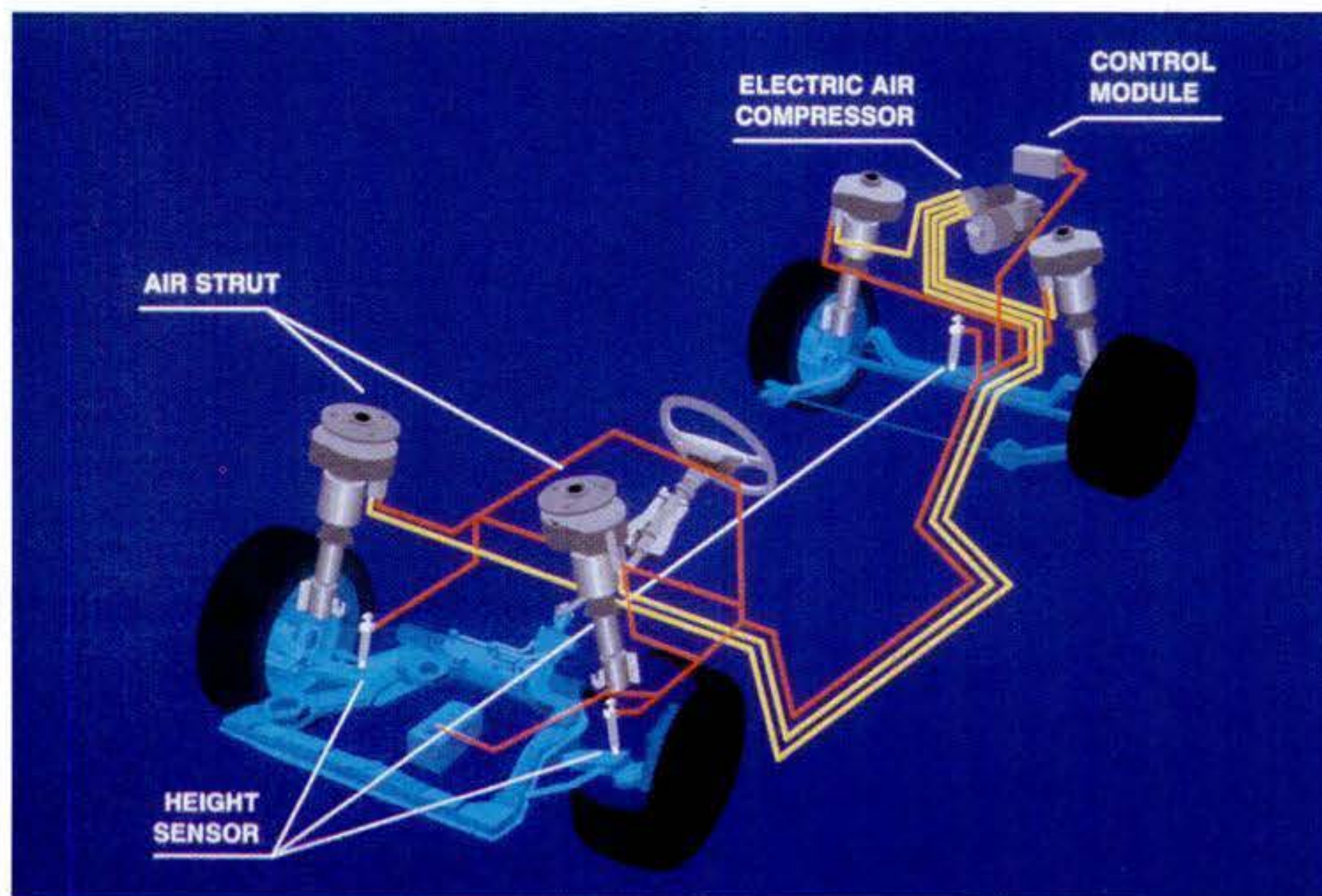
Powered by a high-torque 3.1-liter V6, the Pontiac setup is being eyed by other GM divisions interested in performance 4WD because the Pontiac axle is modular and easily adapts to other GM car lines.

Burning issues

Combustion processes continue to get considerable attention as the search for ever-higher outputs and fuel efficiency continues. Italy's Alfa Romeo recently unveiled yet another ingenious attempt at controlling airflow into the combustion chamber by installing a set of one-way reed valves on each side of the fuel injector. The idea is to trap backflow coming from early-opening valves in the cylinder head, allowing a broad stretch of valve timing. The Alfa engine also features two spark plugs per cylinder, an idea being introduced by Ford this fall on its 2.3-liter four-cylinder Ranger truck engine.

Another rumored effort in the combustion area is a prototype engine at Ford that uses solenoid valve actuation—rather than a camshaft—thus allowing the engine-control computer to select any valve actuation cycle it wants. If this arrangement could be made reliable, it would give engine designers a new way to maximize power and fuel economy across an engine's rpm range. It could also permit the driver to select different driving modes, with a "sport" program giving the best power output and a "cruise" program delivering the lowest fuel consumption.

P 3



In the Lancia system strut air pressures are controlled by an electronic module getting wheel-movement data.

Bag inflation adjusts instantaneously, matching spring rates to road conditions while leveling the car's body.

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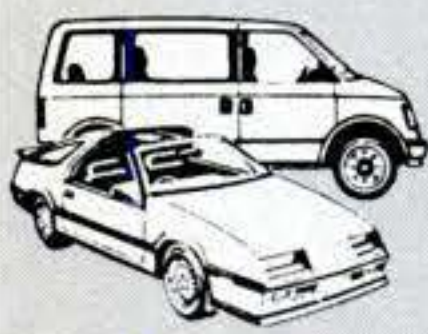
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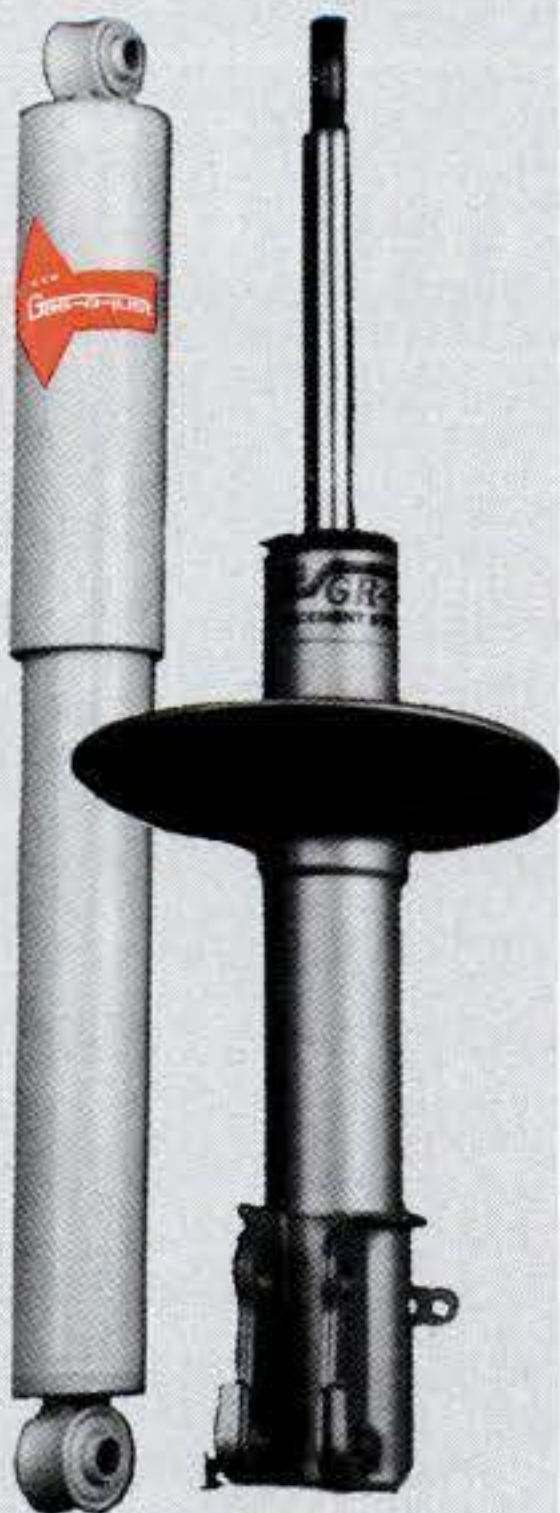


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Passat—VW's new flagship



Low and sleek, Passat combines good looks with solid aerodynamic design.

NICE, FRANCE
With the Volkswagen Passat's four-door notchback body styling, an interior big enough to give a pro football lineman elbow and legroom, and a 103-inch wheelbase, passers-by might be forgiven for assuming that Passat is the German word for "passive." They'd be wrong.

Just now reaching European roads, the updated Passat is a quick-footed fire breather. On a recent jaunt through the twisting mountain highways of the French Riviera, I found the Passat to be a well-mannered driving machine packaged in the trappings of a luxury sedan.

To move up in both class and performance, VW engineers stretched the Passat's wheelbase by three inches to 103 inches, and overall length to 180 inches. Other dimensions are similarly proportioned. To increase interior space in the Passat, VW chose to transversely mount its four-cylinder engine. The engine has been mated with a completely redesigned five-speed manual gearbox that provides precise shifting via steel cables. Steering is also lighter and tighter than I expected.

At just over 2,600 pounds, the Passat sports a 16-valve 136 horsepower four-cylinder engine that provides good pickup with top speeds above 115 mph. For the more frugal minded, VW also offers a more economical engine. An optional anti-lock braking system is available, and the 1990 models will

offer a new traction-control system from Teves.

While the Passat retains its MacPherson-strut front suspension, the



Coming or going, the 103-in. wheelbase provides the sure-footed handling expected of a European luxury sedan.

"track correcting" rear suspension has been improved and toughened. Mounted on rubber bushings and steel wedges, the rear wheels can tilt into a turn. The Passat's cornering ability approaches that of a vehicle with four-wheel steering, says VW engineer Christan Hildebrandt. Yaw and oversteer are greatly reduced.

The Passat's slippery shape has a steeply raked windshield that appears to flow effortlessly from the hood. Body refinements, such as flush-mounted windows and a mini-spoiler on the trunk lid, lowered the car's coefficient of drag to an admirable 0.29.

The interior has ample nooks and crannies for storage and can seat five. There is plenty of electronics for the convenience-oriented crowd, and gauges are traditional analog.

When this sedan reaches the United States sometime in 1990, it will probably have a sticker price above \$17,000.

—Jim Schefter

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"Say, Smokey—"

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Losing your coolant

I have a 1985 Ford Econoline van with a 4.9-liter six-cylinder engine. The radiator does not seem to be able to hold coolant. The dealer has replaced the head gasket, shaved and magnifluted the head, replaced the freeze plug, replaced hoses, and tightened clamps, but still the coolant level keeps dropping. I have never been able to find a leak anywhere, and there is no indication of coolant in the oil. The van now has 41,000 miles on it, and I have added almost a gallon of coolant in the last couple of months. Where is all this coolant going?

David Trask, Richmond, Maine

There are two ways to lose coolant: it can leak out, or it can be consumed. As a general rule of thumb, the trouble is often in the pressure cap, which can leak under the heat and pressure of operating conditions. Here's a way to check for small leaks that are hard to locate: Drain out the coolant and replace it with a mixture of water and a leak-detector dye. This should be available at any good radiator repair shop, along with the black light you will need to illuminate the dye. Run the engine at full coolant pressure (about 20 psi), and look for the dye leaking out, either as a light spray or drops. Check for dye in the engine oil and transmission fluid. Even if the water manages to get into the engine-combustion chamber, the dye will show up in the exhaust system.

Second-hand sludge

I recently purchased a '79 Pontiac with a 301-cubic-inch V8 that had 33,000 original miles on the odometer. It was used almost entirely for short trips. The oil was changed infrequently, and the car had been run low on oil once or twice. I removed one valve cover and found large deposits of sludge on the push rods, scoring of some rocker arms, and one scored valve-stem tip. The engine seems to run well and is quiet on cold start-up but chatters when warm. It sounds as if the noise could be coming from the valve lifters or rocker arms, but there is no rod knock. It gets worse with thinner oil and better with higher viscosity oil. Are there any reliable chemical flushes or oil additives that can help?

Is it a gamble taking this car on a 5,000-mile trip?

Michael Manthe, Brookfield, Wis.

I wouldn't start a 5,000-mile trip with this engine as is. I think you have dirty lifters and some engine wear from inadequate maintenance. Poor quality or the incorrect grade of oil can quickly lead to sludge buildup, especially at high temperatures, when running low on oil, or with a dirty oil filter. No chemical flush will be a bulletproof fix because most of the sludge at this point is static. If you use a chemical cleaner, the sludge will be released into oil circulation and can possibly do some damage by clogging passages. The only sure fix is to pull the engine and disassemble it. Clean and replace the parts that merit it. Anything else is a gamble, and usually you lose.

Gauging the oil gauge

I own a 1986½ Nissan 4×4 truck equipped with a three-liter SE-V6 engine and the full instrument package. For the first 10 months the electronic oil-pressure gauge functioned properly, registering oil pressure consistent with engine speed. At highway speeds it read higher than at idle. Then it began to change, dropping to almost zero, and eventually reading a higher oil pressure at idle than at high speed. At low constant engine speed, it fluctuated up and down. The dealer replaced the sending unit twice as well as checking all wiring for shorts or grounding. However, nothing has returned the gauge to proper working order. The dealer maintains that the oil pump is functioning properly, having checked it with a mechanical gauge. The dealer's explanation is that these electronic gauges frequently fluctuate. Is the dealer correct, and is there any way to fix the gauge?

John Pastelock, McKeesport, Pa.

I would check to see if the gauge or maybe something else is to blame. Temporarily install a mechanical gauge and check its reading for oil pressure against the electronic gauge in the cab at various engine speeds. A good general rule is that there should be 10 psi of oil pressure developed for every 1,000 rpm of engine speed. If the mechanical gauge reads the same as the electronic gauge in the truck, then

there could be a serious problem with the oil pump. But odds are the mechanical gauge will read a reasonable oil pressure, and the fault will be traced to a bad ground or a wiring short in the electronic gauge. I have seen many automotive instruments, especially speedometers, go crazy because of a poor ground.

Smoking update

The advice given to Lorri Peltz-Levis in the December 1987 issue (Smokes Under Duress) may not cure the problem with her 1982 Toyota 4×4 pickup, which smokes while going uphill. I suspect that the oil drain-back hole at the rear of the cylinder head is not large enough, causing the top of the head to fill with oil. The only cure is to remove the cylinder head and enlarge the hole with a die grinder or equivalent tool.

John Brekke, Aurora, Colo.

Thanks for the tip.

Loose axles

Since it was new, my 1983 Chevrolet van has had an annoying rear axle end-play "clunk" that is particularly noticeable when driving on uneven pavement. The clunk can also be produced by moving the rear wheels in and out while the rear end is jacked up. The dealer tells me that this is a common problem, but nothing can be done because there is no provision for axle end-play adjustment.

Don B. De Vore, Helena, Mont.

There is no adjustment, so I can't tell you how to get rid of the noise. But here's an important piece of safety advice: Take off the differential cover and check to see whether the axle retainers are in place and in good condition. It seems that some bad axle parts were made around the time your van was built, resulting in some axles coming unhooked from differentials. If this happens while going around a curve, the vehicle suddenly becomes a three-wheeler. Don't wait to check those retainers.

Got a car problem? Send it to "Say, Smokey—," POPULAR SCIENCE, 380 Madison Ave., New York, N.Y. 10017. All letters are read, and those of widest interest are answered in this column. Due to the large volume of mail, Smokey cannot reply to letters not selected for publication.

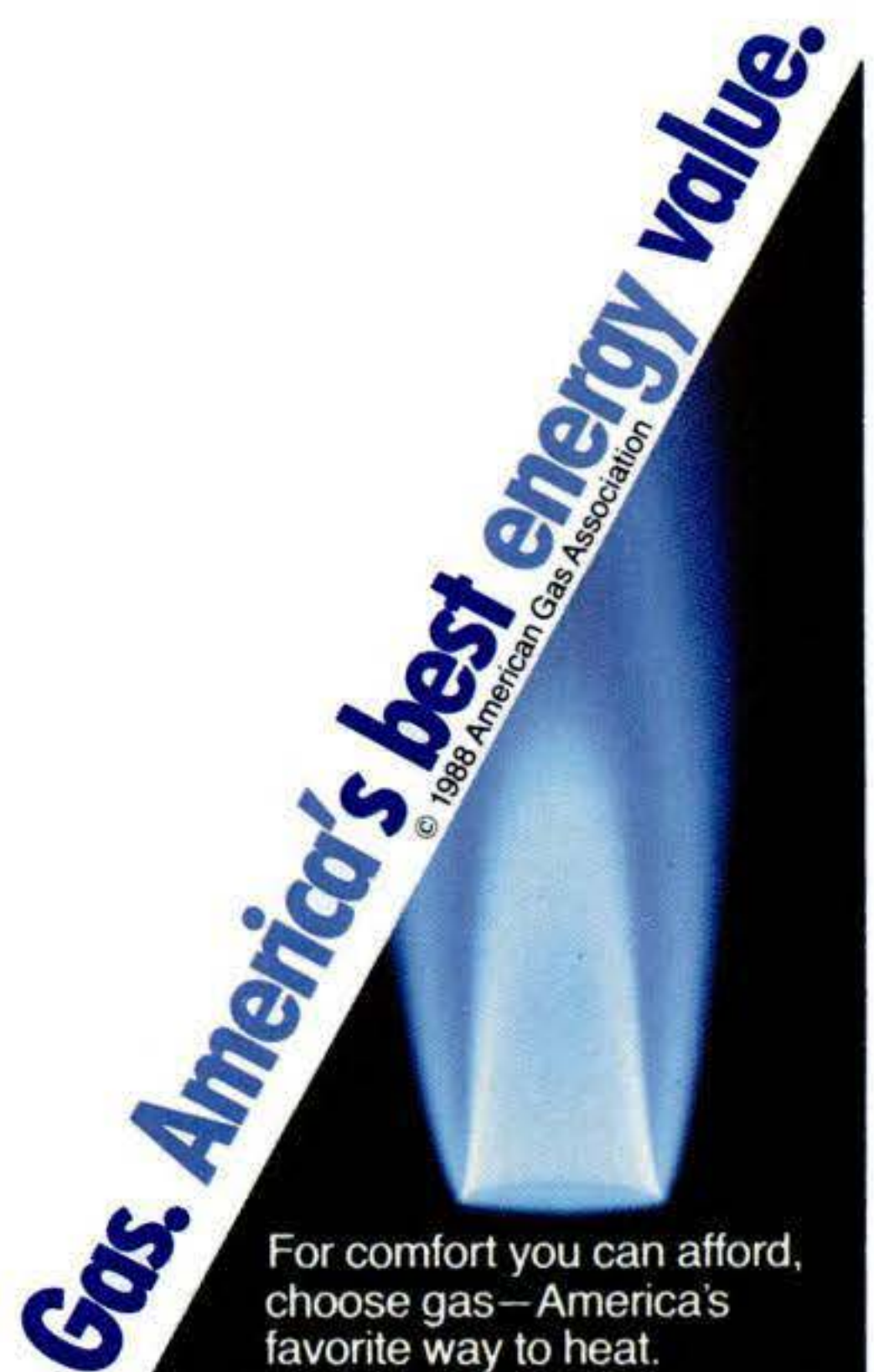
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Call your Trane dealer. Why wait? Upgrade to a high efficiency Trane gas furnace and start saving right away. You'll find your Trane dealer listed in the Yellow Pages.



Electronics Newsfront

By WILLIAM J. HAWKINS

Info to go

Instant information from a device that fits in your pocket? If that sounds good, then you're a prime candidate for a pocket computer, and a variety of manufacturers are waiting in line to sell you one. But there's a rub that most makers don't warn you about: To get information out you've first got to put it in. And that, because of the small keyboard and display, can be a slow, painstaking process. But Psion, maker of the Organiser II, has another way.

I recently tried Psion's Comms Link, a cable that lets the hand-held portable communicate with any PC-compatible computer. I attached one end of the cable to the serial interface connector of my Headstart Turbo-88-XT desk-top computer. I plugged the other end into the top connector on the Psion and pressed the "on" key twice.

The first time I pressed the key, the Psion display showed its usual menu of selections to do such things as finding information (FIND), calculating (CALC), and programming (PROG), using its special built-in language (similar to BASIC). But the display changed when I pressed the key a second time. I then saw a new Comms selection.

I learned that the communications software is held in read-only memory inside the cable connector. When I pressed the key a second time, the Psion computer automatically loaded the program from the cable into its memory for use. To complete the setup, I started a communications program



Psion's Organiser II becomes an extension of your home or your office computer with a communications link.

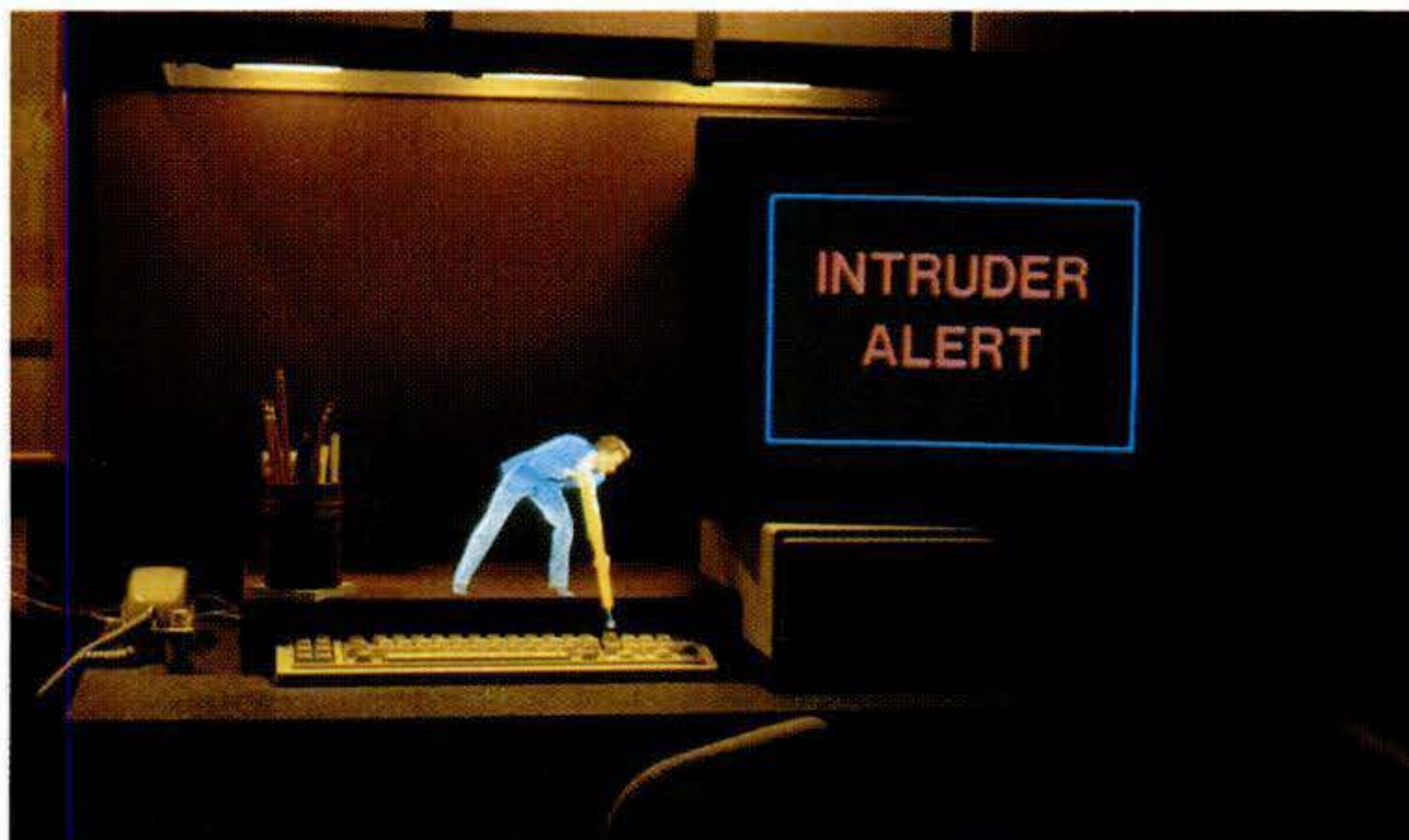
(included on a 5¼-inch floppy diskette) on the desk-top computer.

Result: I now create data on my desk-top machine—mailing lists, shopping lists, price information, programs, telephone numbers, and appointments—and instantly send them to the pocket portable... and vice versa. Additional information that I accumulate on the portable during the day—phone numbers and addresses, for example—can be used to update the desk-top computer's files when I return home. The Comms Link can also be used with a modem for computing via phone lines or with a serial printer for making permanent copies of work while on the go. The \$250 32K computer and \$100 Comms Link are available from Psion Inc., 320 Sylvan Lake Rd., Waretown, Conn. 06779.

Attention grabber

"I thought I was seeing things," Senior Editor V. Elaine Gilmore told me after viewing the AT&T exhibit at a recent convention in Dallas. To get a crowd's attention exhibitors usually hire anything from magicians to talking birds; but AT&T chose Technifex (7430 San Fernando Rd., Sun Valley, Calif. 91352). Technifex uses a system it calls Techniscan to pro-

Continued



Gremlins? A Techniscan-created image quickly grabs your attention.



Instant-on radar: How it works. How to defend yourself.

Instant-on radar—sometimes called “pulse” radar—has been around for years. But it’s being used more frequently now as radar operators try to defeat detector users. Here’s how it works.

First things first

Ordinary radar and instant-on radar use exactly the same type of radar beams. In fact, most radar guns can operate either way. It’s just a matter of which buttons the operator pushes.

How ordinary radar works

In an ordinary radar trap, the radar gun is aimed at traffic and it continuously transmits a beam of radar waves. The effective range for the radar to “see” your speed is less than a half mile for most cars, longer for trucks.

How radar detectors work

A radar detector is a radio receiver tuned to radar frequency. A high-performance radar detector is sensitive enough to pick up the radar waves before you drive within speed-measuring range. It’s as simple as that.

How instant-on radar works

The instant-on radar trap is set up just like an ordinary radar trap. The only difference is that the gun doesn’t transmit until the operator pushes a button. So there is no radar signal for a radar detector to find.

Then when you’re within speed-measuring range, the operator triggers the beam. Hence the term “instant-on.” The radar reads your speed within a fraction of a second, too quickly for a human to respond.

Your only hope

Because instant-on radar is faster than your reflexes, your only defense is to identify it before you are within its range. You must detect it when the operator zaps the traffic ahead of you. For this, your detector must reach out for distant radar signals.



The Kustom Signals HR-12 and KR-11, two of the many radar units that can be operated in an instant-on, or “pulse” mode.

You’re looking for weak radar that lasts only a few seconds. Finding even one such “pulse” is cause for alert. Finding a series of them, each stronger than the previous one, indicates you’re approaching an instant-on radar trap that’s picking off traffic ahead.

Same old strategy

Identifying instant-on radar before you come in range is the only defense today, just as it was when we first introduced Escort. That’s why our warning system, used on both Escort and Passport, tells you both the strength of the signal and the length of it. You need to know both to defend yourself.

Nothing but the truth

Our warning system indicates signal strength two ways: by a meter for a visual check, by a variable-rate beeper if you prefer to listen. The length of the signal is indicated by the duration of the alert. Knowing signal strength and signal length of every radar encounter is the only way to find instant-on radar before it finds you.

Escort and Passport are the most effective radar-warning instruments available. But don’t take our word for it.

In 1987, *Car and Driver*, *Popular Mechanics* and *Roundel* each published independent tests of radar detectors. And each gave us the highest ratings. Call toll-free and we’ll send reprints of the complete tests, not just excerpts or quotes.

We’re as close as your phone

We sell direct to you, and we guarantee your satisfaction. If you’re not entirely satisfied within 30 days, return your purchase. We’ll refund your money and shipping costs.

To order, call toll-free. Orders in by 5:00 pm eastern time go out the same day by UPS and we pay the shipping. Overnight delivery is guaranteed by Federal Express for only \$10 extra.

Call now and the best defense against instant-on radar can be in your car tomorrow.

Order Today

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DOING IT WRONG

When you understand that instant-on is nothing more than ordinary radar being turned on and off, the threat loses its mystery. Defense comes down to detecting the radar before it’s strong enough to find you.

Baloney breakthrough. The latest Whistler Spectrum 2 has a feature called “Pulse Protection.” Here’s what it does. When this unit detects the sudden presence of a high-

strength signal, a “P” appears on its display and it sounds a special alarm. This is your “Pulse Protection.”

The fine print. Unfortunately, the sudden presence of a high-strength signal describes an instant-on encounter when you’re already within range. True protection from instant-on depends on responding before you are within range, which means responding to weak signals. But “Pulse Protection” doesn’t respond to weak signals.

Whistler says this feature “tells you when you’re being shot at.” And that’s the problem. When you’re being shot at, it’s too late.

duce three-dimensional images that seem to be at home crawling all over the exhibitor's products (see photo). Technifex claims the images are not holograms... and won't say more.

Non-fat 386

About a week after Intel introduced its new 386SX microprocessor, Compaq showed it in a new PC. The chip works like a standard 80386, except it's 15 percent slower and missing a couple of programming features that are seldom used. But its advantage is a hefty saving—a computer that uses a 386SX is about \$1,000 less than a straight 386.

Laser printer with no laser

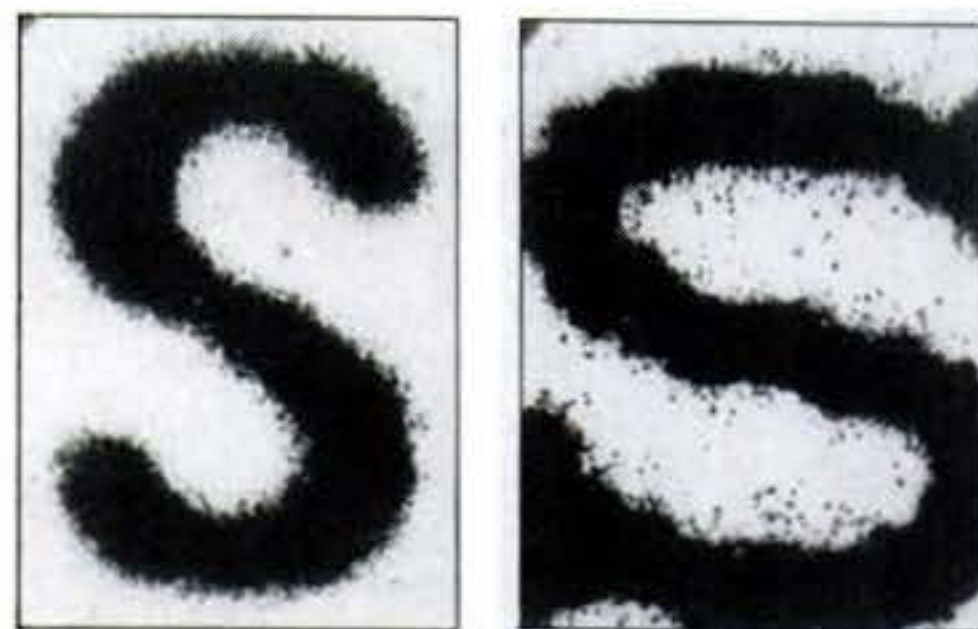
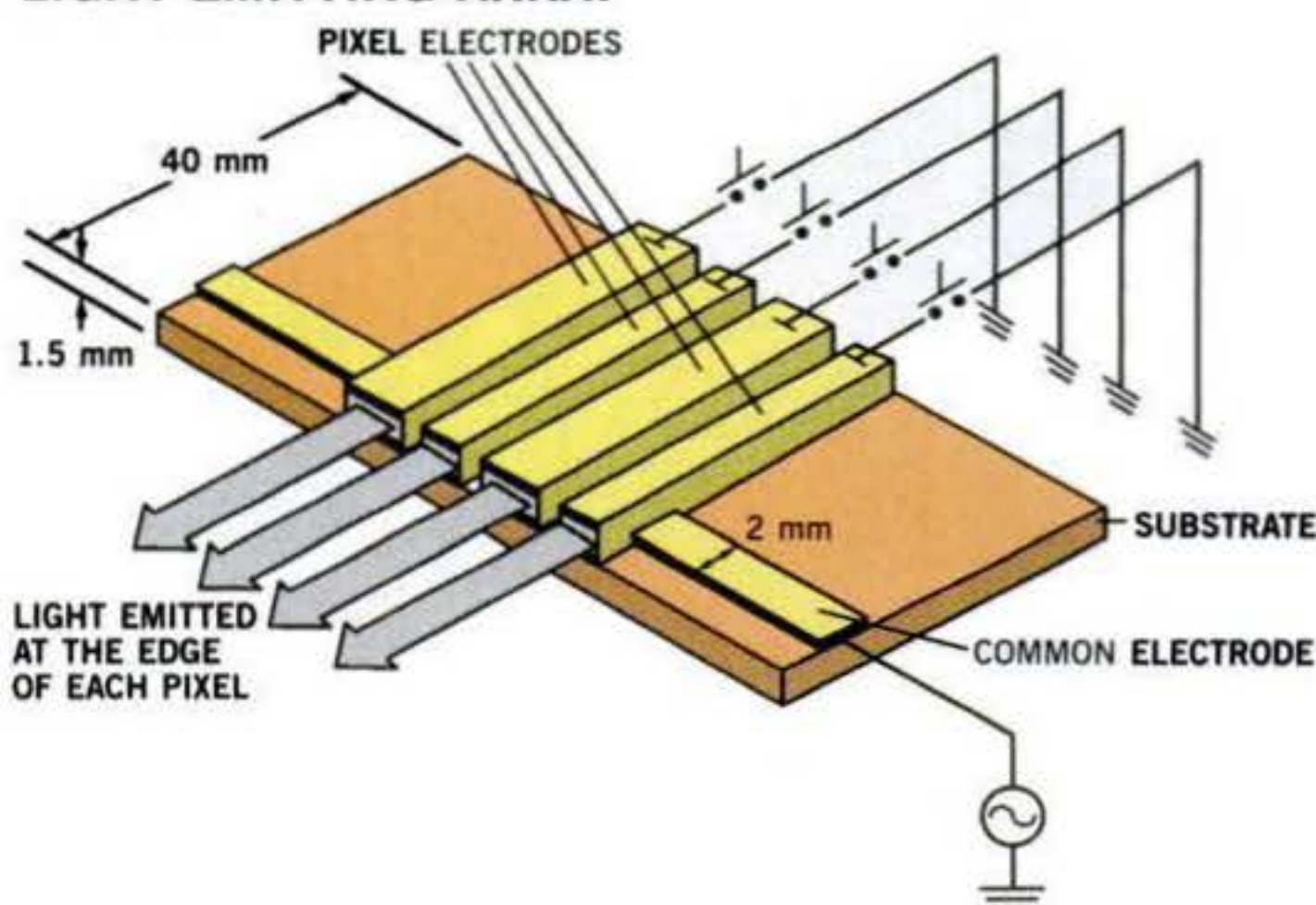
Scientists at the Westinghouse Research & Development Center in Pittsburgh removed the laser from a laser printer and replaced it with a thin-film electroluminescent edge emitter. Unlike a laser, which must be swept across the paper for printing, the solid-state edge emitter uses separate light-emitting segments, so no scan-

ning mirrors or moving parts are needed. That makes it more reliable and much smaller than a laser print head. The Westinghouse printer can turn out up to 20 pages a minute with a resolution of up to 400 dots per inch. Says advisory engineer Zoltan K. Kun, "We expect to go up to one thousand dots per inch." The print quality seems to be better than that from a laser, and the laserless printer could be cheaper; but at present the company has no manufacturing plans.

High-definition disc

Matsushita Electric Corp. has developed the first high-definition (1,125 lines) optical-disc recording system. The disc can hold 600 still pictures or 500 still pictures with one hour of digital stereo audio.

LIGHT-EMITTING ARRAY



Segments on Westinghouse's edge emitter create a sharper image: Compare S at left with laser-printed S on right.

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Save Gas, Save Engine with 'POLY'

GUARANTEED LOWEST PRICE (SEE DETAILS BELOW)

The following introduces one of the most fully tested and credentialed gas saving, friction reducing engine treatments ever to reach the market!

WHAT IS POLY? "Poly" is short for polytetrafluoroethylene (TFE). It is the slipperiest substance known to man (1981 Guinness Book of World Records, p. 188). The PetroLun Corporation, makers of Slick 50, has invented a way to permanently bind this slippery chemical to your engine with one treatment. All you do is add one quart of Slick 50 to your oil during oil and filter change. By reducing engine friction, Slick 50 increases gas mileage and horsepower and reduces engine operating temperature thus causing your oil and engine to last longer. Just as important, it reduces metal wear, defraying costly overhauls.

HOW DO I KNOW THIS ISN'T A FRAUD? Slick 50 has some very impressive credentials. The "Consumers Digest" magazine (March/April 1982, p. 35) states "Slick 50 does reduce engine heat and ordinary wear, and our informal tests indicate that it will improve gas mileage by about two or three miles per gallon. . . . Slick 50 does exactly what PetroLun claims it does." Researchers at a nationally respected research laboratory, after applying a powerful ultrasonic cleaning process to a Slick 50 treated engine part, were surprised at its permanence. They stated, "We actually expected the PetroLun Slick 50 TFE Resin coating to also be removed, but later found it was still there."

The Federal Aviation Administration has fully accepted a similar product- Slick 50 Aircraft Treatment (F.A.R. #33.49). An FAA test simulating 1400 hours of engine use showed almost zero engine wear!

TUV, a German testing laboratory with credentials every bit as prestigious as our Underwriters Laboratories, tested Slick 50 in 1986. They found substantial increases in both gas mileage and horsepower. Their tests showed that these gains were due to a reduction in friction.

A test done at the San Diego State University revealed that, "Slick 50 does increase horsepower and decreases fuel consumption in tests done at the university." The Space Shuttle Columbia uses the chemical "poly" in its gears and bearings because it is the only chemical lubricant which can withstand the heat and corrosive elements of space.

Perhaps the most dramatic of all is a torture-test overseen by the Automotive Services Council for Pennsyl-



vania and shown on television station WTVE. Three cars with between 75,000 and 129,000 miles on them were treated with Slick 50. Six months later the oil was drained from each vehicle and the cars were driven without the oil plugs for about a half hour. The water temperature never rose and the engines sustained no apparent damage.

HOW DO YOU TREAT AN ENGINE? Very simply. Just before oil and filter change, add engine flush (sent free with each order) to clean out your engine. Let your engine idle for 5 minutes. Then drain your oil, change filter and add the proper amount of oil less one quart. Add one quart Slick 50, drive for 30 minutes, and leave it in the crankcase for 3,000 miles. Add two quarts for engines with oil capacities of seven quarts or more.

Slick 50 gives a permanent coating so you need to treat only once, not each time you change oil. Slick 50 is also excellent for turbocharged engines, aluminum block engines and rotary engines.

WILL IT WORK WITH MOST OIL? Yes, Slick 50 will work with all petroleum based oils and all synthetics compatible with petroleum based oils.

WHAT ARE THE BENEFITS OF SLICK 50? Your actual benefits in percentages may vary, depending on the kind of driving you do, vehicle condition, etc. By reducing friction, Slick 50 does all of the following: it increases gas mileage. It increases horsepower -- small economy cars and large RV's really need this. It makes for easier starting (important

in cold weather). It reduces operating temperatures, thus increasing the lubrication and life of your oil and your engine. Since lubricating lead is being removed from gas and unleaded gas is poor in lubricating qualities, the extra lubrication of Slick 50 on valve stems and guides is very valuable. Last, but not least, the drastic reduction in engine wear can delay costly overhauls which can in fact cost well over \$1,000. Slick 50 eliminates the "lubrication starvation" that all cars experience when first started before the oil has a chance to circulate. Up to 90% of the wear on a car can be caused by this lubrication starvation. You receive all of these benefits for less than the cost of two tanks of gas (\$39.95).

WILL SLICK 50 HARM MY ENGINE OR AFFECT MY WARRANTY? No! Slick 50 is suspended in an excellent grade of petroleum oil which meets or exceeds every manufacturers engine warranty requirements. In addition, this oil carries an API (American Petroleum Institute) service classification SF-CC-CD.

DEALERSHIPS ARE AVAILABLE. **OTHER SLICK 50 PRODUCTS** available are Gear Treatment (manual transmission, etc.), 2-Cycle Engine Treatment, Grease, Fuel Conditioner, and Fabric Protector. Free information is sent upon request.

EASY TOLL FREE NUMBER. Since Slick 50 is "too too Slick" for engine friction, our toll free number is 1-800-22-SLICK (that is, 1-800-227-5425).

Free engine flush sent with each order. Free shipping with orders of 2 or more.

For purchase or further information call toll free 1-800-22-SLICK, (in Colorado, call 1-303-772-4797) or send to: FORT MORGAN SLICK 50, 407 Del Rio Road, Berthoud, Colorado 80513.

GUARANTEED LOWEST PRICE! If at time of purchase you have seen Slick 50 advertised in a current magazine at a lower price, we will beat that price by \$2.00 per quart.

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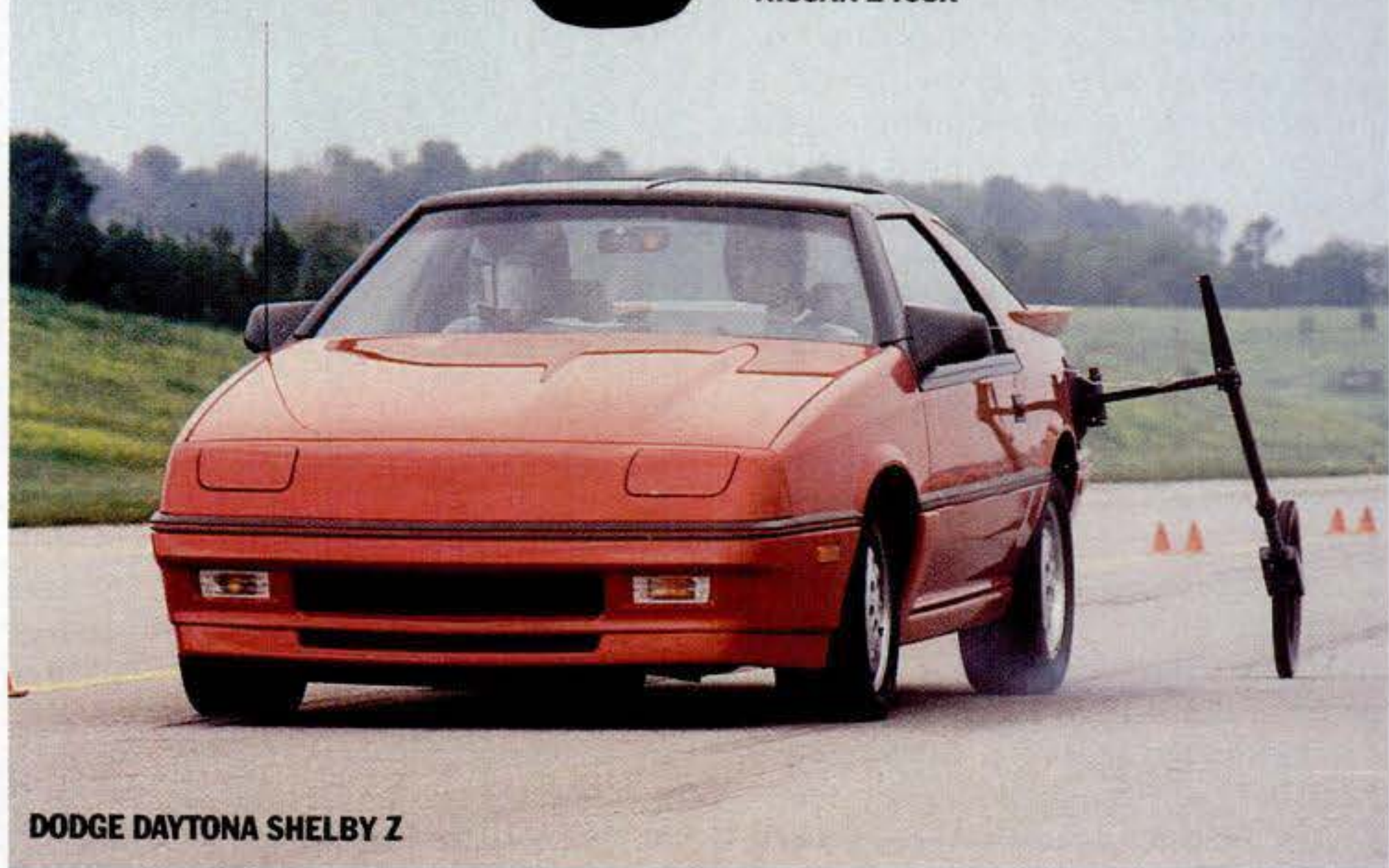
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PHOTO BY TERRY BAKER

Three of POPULAR SCIENCE's instrumented tests are demonstrated by the six competing coupes in action. The Toyota Celica reveals no lockup in fifth-wheel-equipped panic braking, while the Dodge Daytona comes to a slightly smoky stop as it locks the front wheels. The Ford Probe easily snakes through the maneuverability slalom on the way to a second-place finish. In the high-speed handling test, the Mazda MX-6 displays some body roll, while the Chevy Beretta and Nissan 240SX maintain an even keel.

NISSAN 240SX



DODGE DAYTONA SHELBY Z

6

QUICK COUPES

One of the hottest classes of cars in the marketplace got hotter this year with the introduction of the sizzling Ford Probe GT and the just-unveiled Nissan 240SX. The group—small, fast, nimble sports coupes—is epitomized by the flagship Toyota Celica GT-S and the Mazda MX-6 Turbo, Dodge Daytona Shelby Z, and 1988½ Chevrolet Beretta GTU. The POPULAR SCIENCE team tests the mettle of these six cars to find out which is best.

By DAN McCOSH and DON SHERMAN





TOYOTA CELICA GT-S

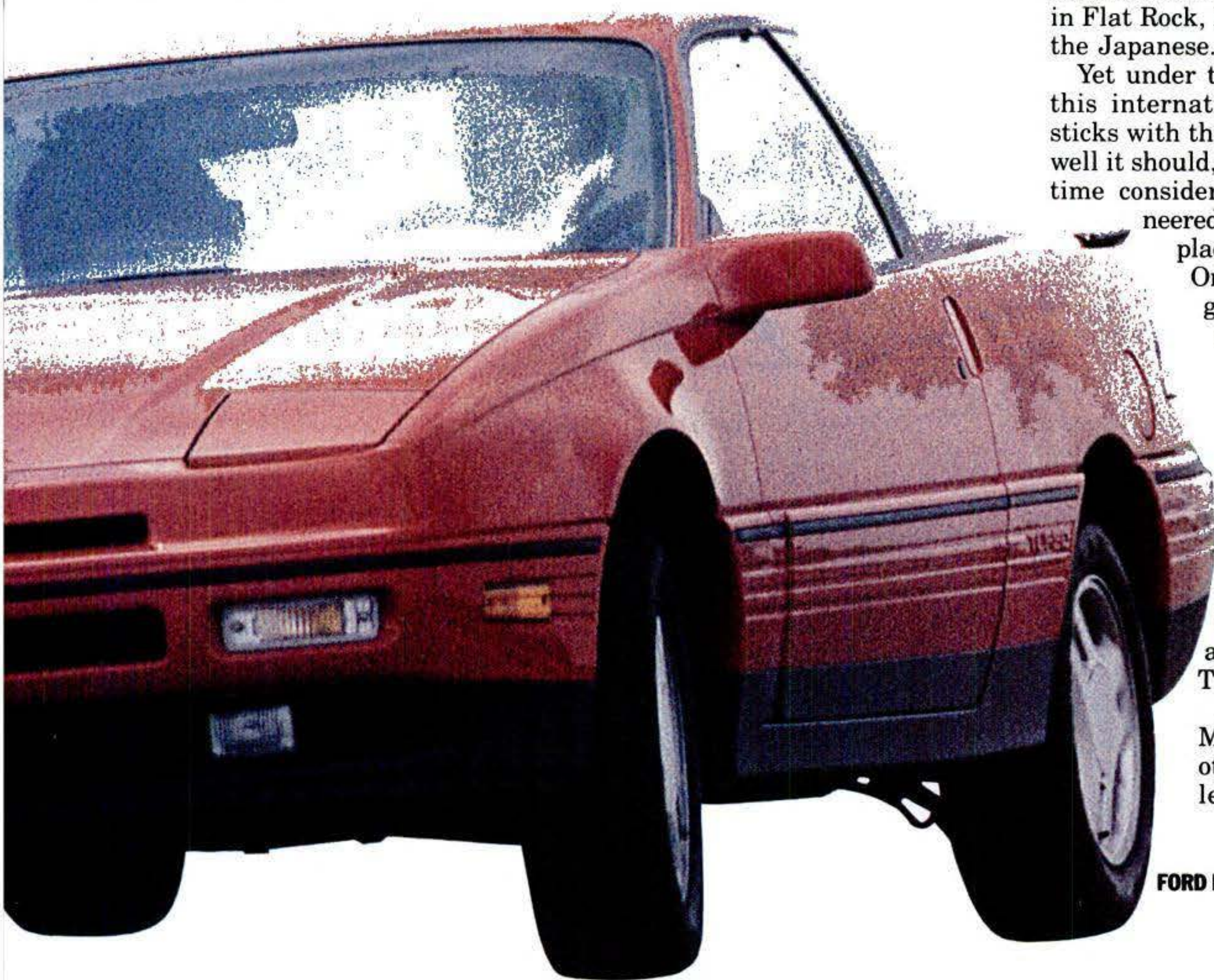


CHEVROLET BERETTA GTU

PHOTOS BY GREG SHARKO



MAZDA MX-6 TURBO



FORD PROBE GT

The original Ford Mustang set a formula for sporty cars that's lasted for two decades: a big engine plus a sexy coupe body on a chassis modified from a basic sedan. The recipe worked even better for the Japanese, because cars like the Toyota Celica and Honda Prelude offered smaller proportions with more engine displacement.

Now comes Ford Motor Co.'s new Probe, one of the newest entries in the category—marking a growing trend toward cross-fertilization in the auto industry. It wraps a body designed at Ford around a chassis engineered by Mazda Motor Corp. The car is built in Flat Rock, Mich., in a plant run by the Japanese.

Yet under the skin, the product of this international partnership still sticks with the Mustang formula—as well it should, because Ford for a long time considered the Japanese-engineered Probe as a potential replacement for the Mustang.

Only this time, the Probe's genesis was a Mazda 626 sedan—a basic chassis also shared with Mazda's MX-6 Coupe.

The Ford Probe is challenging a crowd of similar cars, including the likes of the Toyota Celica, Honda's Prelude [“4-Wheel Steer vs. 2-Wheel Steer,” March] and Subaru's XT Coupe. The POPULAR SCIENCE test group of the Probe GT, Mazda MX-6 Turbo, Toyota Celica GT-S, Chevrolet Beretta GTU, Dodge

Continued

6 quick coupes *Continued*

Daytona Shelby Z, and Nissan 240SX was selected to include a half dozen domestic and Japanese competitors—mid-priced mid-size sporty cars that offer most of the performance of a flat-out two-seater with some amenities, including a back seat.

Half of the cars were turbocharged; the other half had high-output power plants. The cars also had powerful brakes and sticky tires, and they all had suspensions tuned primarily for performance.

In the power department, Mazda's 2.2-liter power plant, shared by the Probe and MX-6, quickly set the tone. The test cars were turbocharged, which kicks horsepower up to 145 at 4,300 rpm, with a torque rating of 190 pound-feet at 3,500 rpm. The Probe and MX-6 are also available with a non-turbocharged 110-hp version of the engine.

The engine breathes through two intake valves with a single exhaust valve, making it a 12-valve engine. Triplet valving, triggered by a single overhead camshaft, is a less expensive design route than that of the new 16-valve engines, while offering most of the benefits of less constricted fuel-air flow.

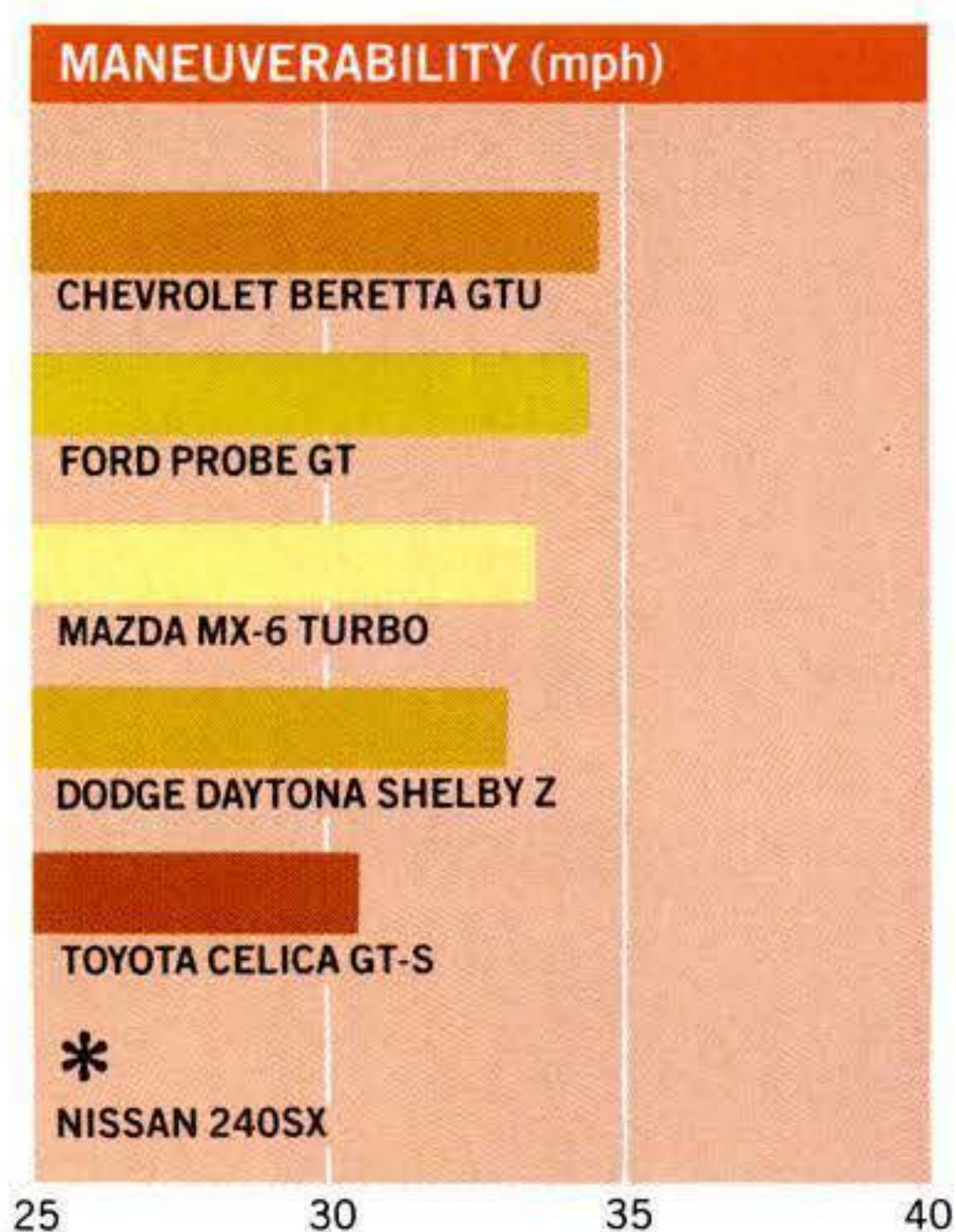
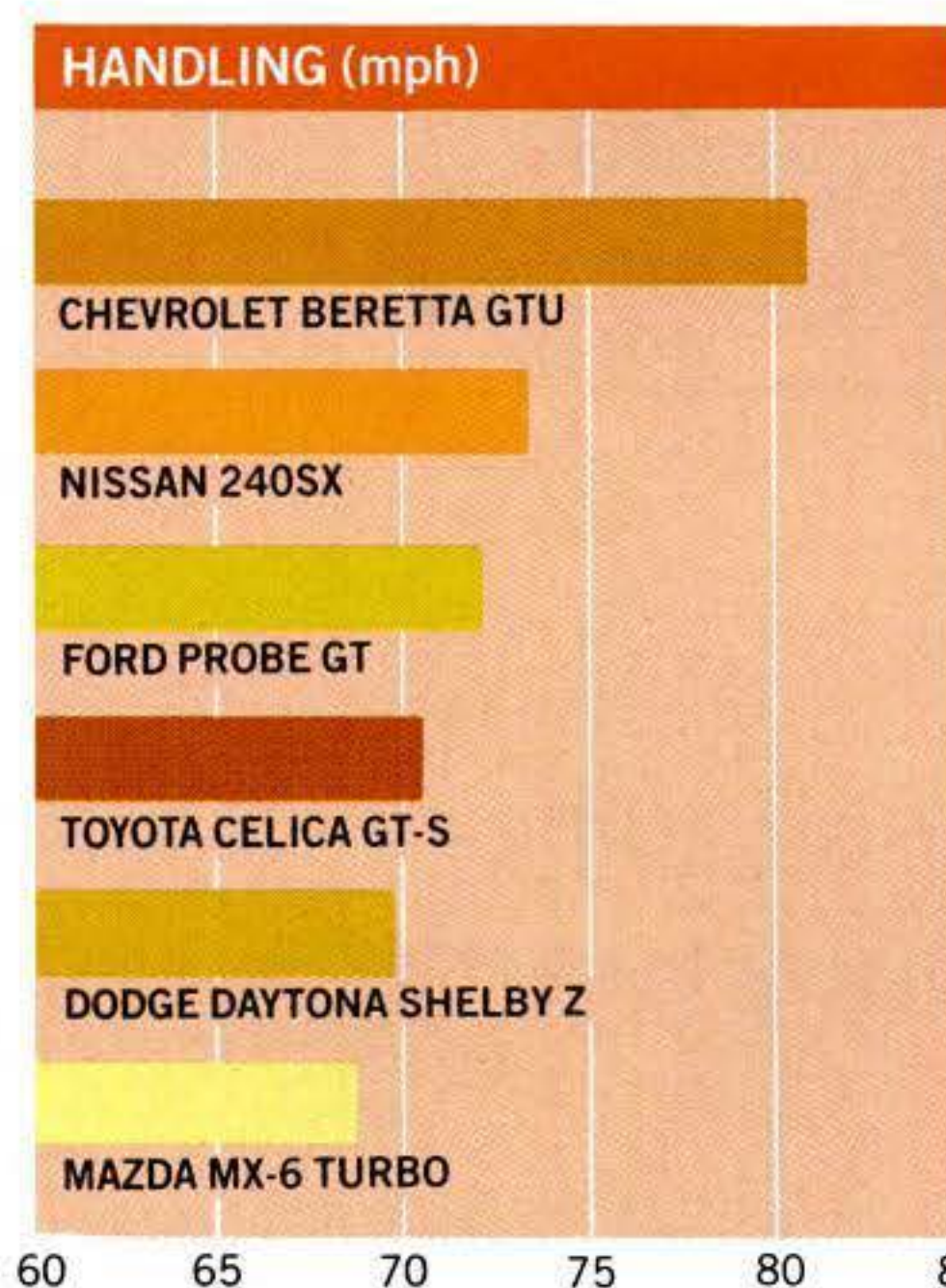
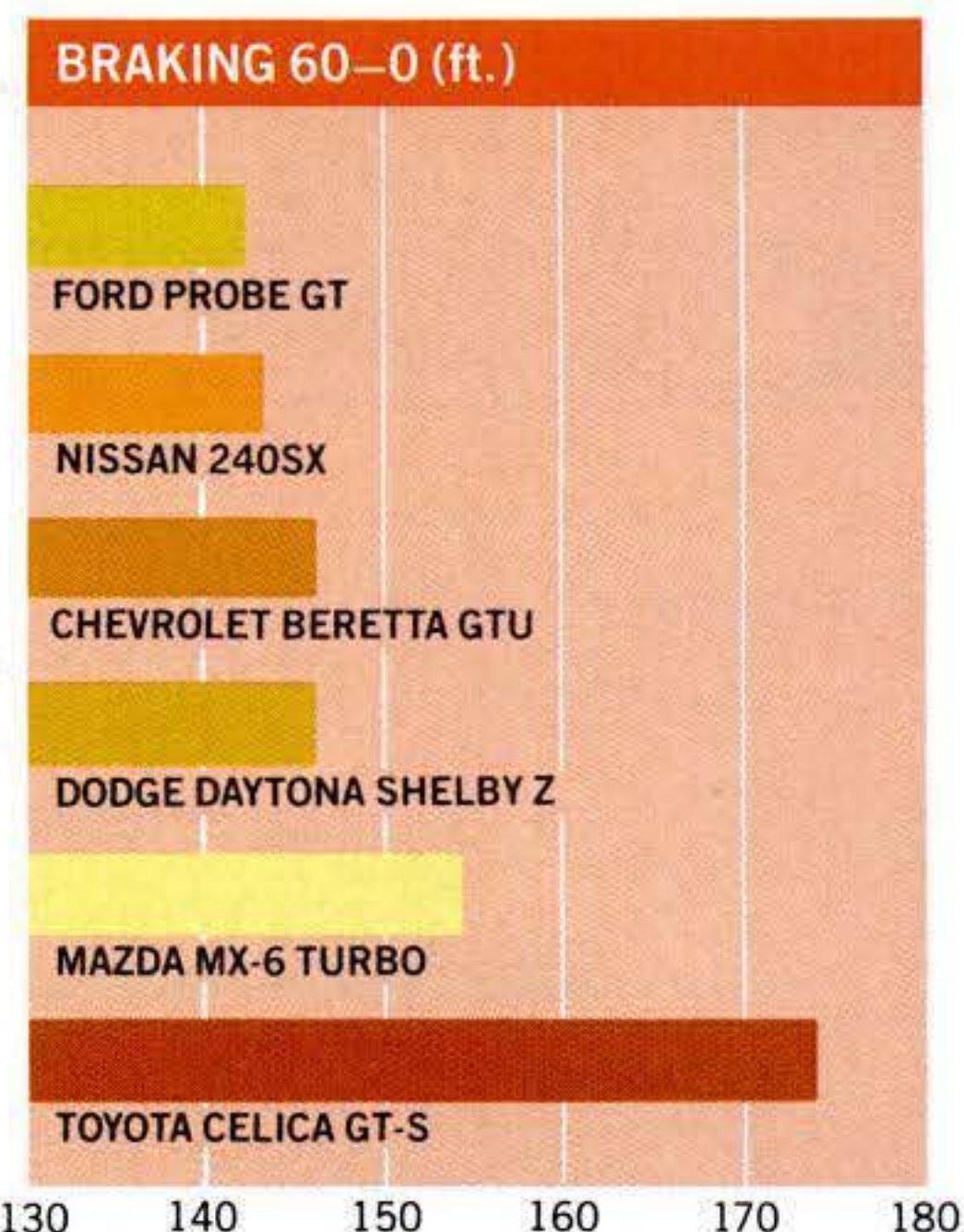
Hot—but not searing—cars

Power ratings for the Probe are identical to those of the MX-6, but the Probe is more than 150 pounds heavier, one reason why the MX-6's 0-to-60-mph time of 8.1 seconds edged out the Probe by about a tenth of a second for fastest time of the day. (Although an eight-second run is quick enough to keep you from being embarrassed by other cars in the class, previously we had clocked a 6.8-second 0-to-60-run with a hardtop Mustang GT—which is likely one reason why Ford hastily dropped its original plan to replace the Mustang with the Probe.)

Chrysler's Daytona, with its 174-hp 2.2-liter turbocharged engine, was the only close runner-up to the Probe/Mazda duo in raw acceleration, clipping through the course in 8.4 seconds. We were pleased to note that the Daytona's gearshift was a major improvement in slickness over previous Chrysler five-speeds *POPULAR SCIENCE* has tested.

The remainder of the cars were grouped in a relatively slow cluster in the 10-second range, the result of either low horsepower-to-weight ratios or lower-horsepower engines.

The Chevy Beretta's 2.8-liter V6 produces 130 hp at 4,700 rpm, the lowest specific output in the group, with a healthy 160 lb.-ft. of torque at 3,600 rpm. This made for leisurely 0-to-60-mph runs of 10 seconds. The pre-pro-



*Not available; test equipment failure

duction Nissan 240SX clocked 10.2 seconds—still a bit quicker than the Celica's 10.8.

Cars that go quickly must also stop quickly. The GT and turbo packages in this group included four-wheel disc brakes on all the cars except the Beretta GTU, with the Probe and MX-6 also adding anti-lock braking. The result was that five of the six cars did panic stops in or near the 140-to-150-foot range; the shortest distance was the Probe's 142-foot stop. The only weak car in braking was the Toyota Celica, which faded slightly on a longish 174-foot stop despite its four-wheel disc brakes.

Handling nuances

Trying to sort out the handling potential of the cars turned out to be more a judge of character than all-out performance. The Probe and MX-6

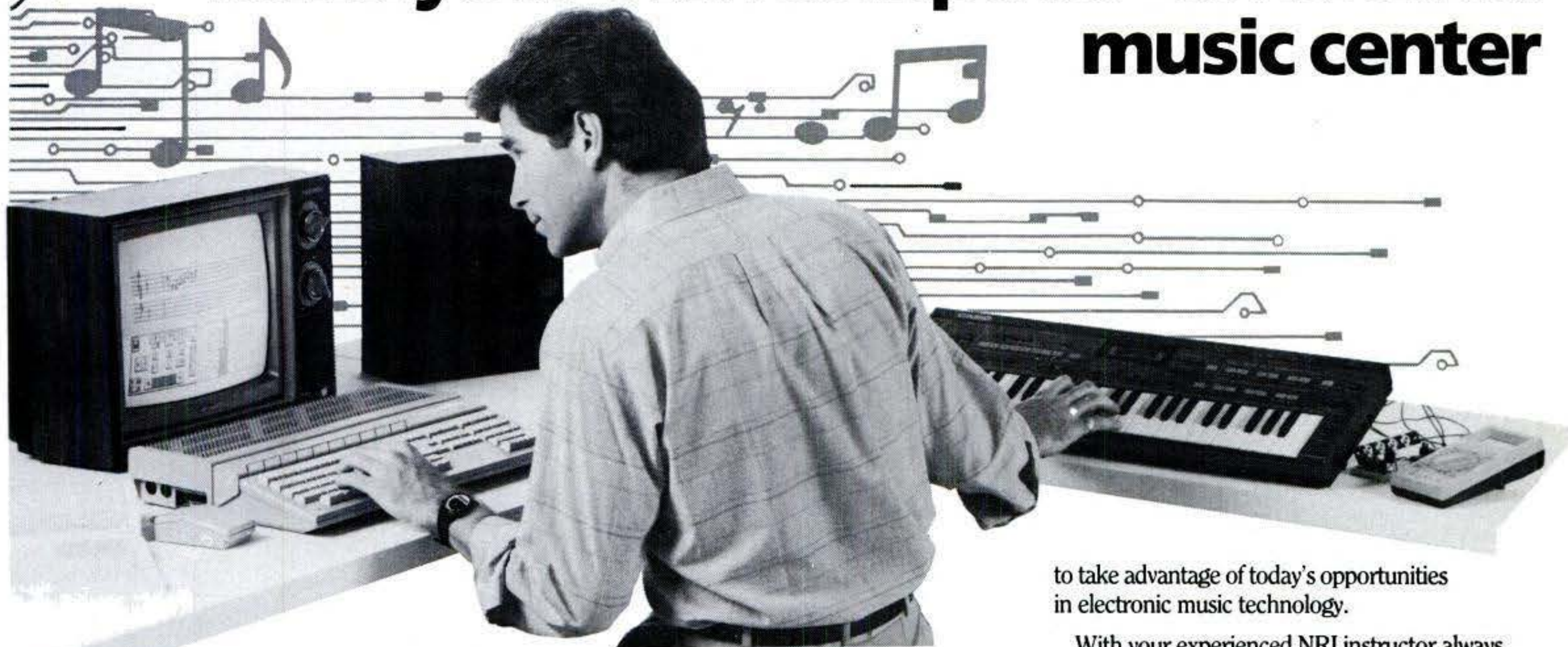
share some suspension similarities with the new Mazda 626. Both cars feature speed-sensitive variable shock-absorber valving (which was left in the "firm" setting for our tests). Independent front struts are paired with a rear suspension that uses asymmetrical bushings that progressively toe in under load. It's a system being adopted in various forms by other car makers as well. The variable-toe feature is a quick-and-dirty way of achieving some of the effects of the computer-assisted four-wheel steering that is offered on the 626, mainly keeping the rear end in line in evasive maneuvers. The result was a 68.7-mph run for the MX-6 through the high-speed pylons with good control.

But Ford has a different notion about how a GT-type car ought to handle. The Probe has stiffer springs, a thicker

[\[Continued on page 40\]](#)

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POPULAR SCIENCE TEST RESULTS

	Chevrolet Beretta GTU	Dodge Daytona Shelby Z	Ford Probe GT	Mazda MX-6 Turbo	Nissan 240SX	Toyota Celica GT-S
TEST RESULTS						
Acceleration (sec.)						
0-30 mph	2.8	3.0	2.5	2.6	2.9	3.2
0-60 mph	10.0	8.4	8.2	8.1	10.2	10.8
Brake test 60-0 mph						
Stopping distance (ft.)	146	146	142	154	143	174
Pedal pressure, cold (lbs.)						
(0.5-G stop)	9	10	12.5	12	12	12.5
Pedal pressure, hot (lbs.)						
(0.5-G stop)	8	6	12	8	15	15
Handling test (mph)	80.8	69.8	72.1	68.7	73.3	70.4
Maneuverability test (mph)	34.6	33.1	34.4	33.4	n.a.*	30.4
Interior noise (dBA)						
At idle	51	56	42	43	52	44
At 60 mph	67	69	66	66	70	67
EPA FUEL MILEAGE (mpg)						
Highway	27	29	27	28	32	29
City	19	21	21	21	22	23

*Not available

Dimensions and specs

DIMENSIONS (in.)						
Wheelbase	103.4	97.0	99.0	99.0	97.4	99.4
Overall length	187.2	175.9	177.0	177.0	178.0	173.6
Overall width	68.2	69.8	68.5	66.5	66.5	67.3
Overall height	55.3	51.3	51.8	53.5	50.8	49.8
SPECIFICATIONS (as tested)						
Engine type	V6	In-line turbo 4	In-line turbo 4	In-line turbo 4	In-line 4	In-line 4
Displacement (cu. in./liters)	173/2.8	135/2.2	133.3/2.2	133/2.2	146/2.4	121/2.0
Compression ratio	8.9:1	8:1	7.8:1	7.8:1	9.1:1	9.2:1
Induction	FI	FI	FI	FI	FI	FI
Net horsepower @ rpm	130 @ 4,700	174 @ 5,200	145 @ 4,300	145 @ 4,300	140 @ 5,600	135 @ 6,000
Net torque (lb.-ft.) @ rpm	160 @ 3,600	200 @ 2,400	190 @ 3,500	190 @ 3,500	152 @ 4,400	125 @ 4,800
Transmission	5-speed manual	5-speed manual	5-speed manual	5-speed manual	5-speed manual	5-speed manual
Final drive ratio	3.61:1	2.86:1	4.1:1	4.105:1	4.11:1	4.176:1
Steering	Power assist rack and pinion	Power assist rack and pinion	Power assist rack and pinion	Power assist rack and pinion	Power rack and pinion	Power assist rack and pinion
Turn diameter (ft.)	n.a.*	40.7	34.1	37.3	30.8	35.4
Front suspension	MacPherson strut with coil springs	Iso strut, coil springs, linkless stabilizer bar	MacPherson strut, asymmetrical control arms, upper strut-mounted coil springs, stabilizer bar	MacPherson strut, asymmetrical control arms, coil springs, anti-roll bar	Independent, MacPherson struts	MacPherson strut with offset coil springs, joint-type stabilizer bar
Rear suspension	Trailing arm with tubular control arms and open section transverse beam	Trailing flex-arm with tract bar	Independent strut, four bar with single trailing arm, upper strut-mounted coil springs, stabilizer bar	Independent single trailing arms, twin trapezoidal links, coil springs, anti-roll bar	Independent, multiple link	Independent dual link, offset coil springs, joint-type stabilizer bar
Brakes	Disc/drum	Disc/disc	Disc/disc	Disc/disc	Disc/disc	Disc/disc
Curb weight (lbs.)	2,608	2,830	2,870	2,705	2,690	2,606
F/R weight distribution (%)	64/36	62/38	64/36	63/37	53/47	62/38
Fuel tank (gal.)	13.6	14.0	15.1	15.9	15.9	15.9
Trunk volume (cu. ft.)	13.5	17.1	11.9	15.4	14.2	11.9
Base price	\$10,135	\$12,601	\$13,593	\$15,099	\$13,000	\$14,898
Price as tested	\$14,493 ¹	\$16,574 ²	\$16,276 ³	\$18,099 ⁴	n.a.	\$17,943 ⁵

Major options (over \$100): ¹GT package \$2,663, GTU package \$2,500, radio \$150, rear defogger \$145, package discount -\$1,100; ²A/C, power heated remote mirrors, power locks, front floor mats \$1,250 (package), T-bar roof package \$1,246, leather bucket seats \$939, Infinity II sound system \$210, cargo trim/quiet sound package \$203, liftgate wiper/washer \$125; discount -\$350; ³trip computer, rear washer/wiper, illuminated entry system, speed control, power drive seat, ABS, power windows, power locks, leather-wrapped steering wheel, premium sound, vehicle maintenance monitor, walk-in passenger seat, climate control \$3,569 (package), discount -\$888; ⁴ABS \$1,395, A/C \$795, moon roof \$650, burglar alarm \$160; ⁵A/C \$960, sun roof \$660, stereo \$430, power locks and windows, electric mirrors with defoggers \$380, burglar alarm \$350, cruise control \$205 *Not available

Parts and service

PART PRICES (manufacturer's suggested retail)						
Brake pads, front	\$ 50	\$ 84	\$ 97	\$ 43	\$ n.a.*	\$ 29
Brake pads/linings, rear	50	77	32	43	n.a.	29
Front shock/strut insert	143	50 ¹	76	76	n.a.	n.a.
Alternator	140	164	233	182	n.a.	451
Fuel pump	86	239	n.a.	n.a.	n.a.	297
Ignition module	None	296	69	784	n.a.	211
Grille	40	263	882	114	n.a.	103
Front bumper	265	145		433	n.a.	145
Windshield	435	270	369	236	n.a.	248
Taillight lens	Inner: 24 Outer: 68	71 ²	30	143	n.a.	69

*Not available ¹For assembly; insert not available ²For assembly; lens not available

PS serviceability ratings

Checking oil level	5	5	5	5	4	5
Checking coolant level	5	4	5	5	4	5
Adding oil	5	5	5	5	4	5
Changing oil filter	4	5	3	3	4	4
Changing spark plugs	2	5	5	5	5	5
Changing belts	3	4	3	3	4	3
Changing radiator hoses	3	5	3	3	4	4
Changing heater hoses	3	4	3	3	4	3
Checking fuses	3	3	4	4	4	5
Spare-tire access	4	4	4	4	4	4

(Ease of service: 5 = excellent, 1 = poor)

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Simply put, the XT6 boasts a combination of features not found on any car. At any price.

In fact, it's the only car of its kind to utilize a computerized full time 4 wheel drive system.

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powered by Subaru's first aluminum alloy overhead cam 6 cylinder engine.

Recent innovations like on board computers and self-adjusting air suspension are also offered.

And if you haven't guessed

by looking at it, the XT6 is one of the most aerodynamic production cars in the world.

All of which makes this Subaru's "un-Mercedes-like"

price even more astounding. You can purchase an XT for as little as \$10,216*.

The Subaru XT6. The car that finally ends the myth that high technology may only be purchased at a high price.



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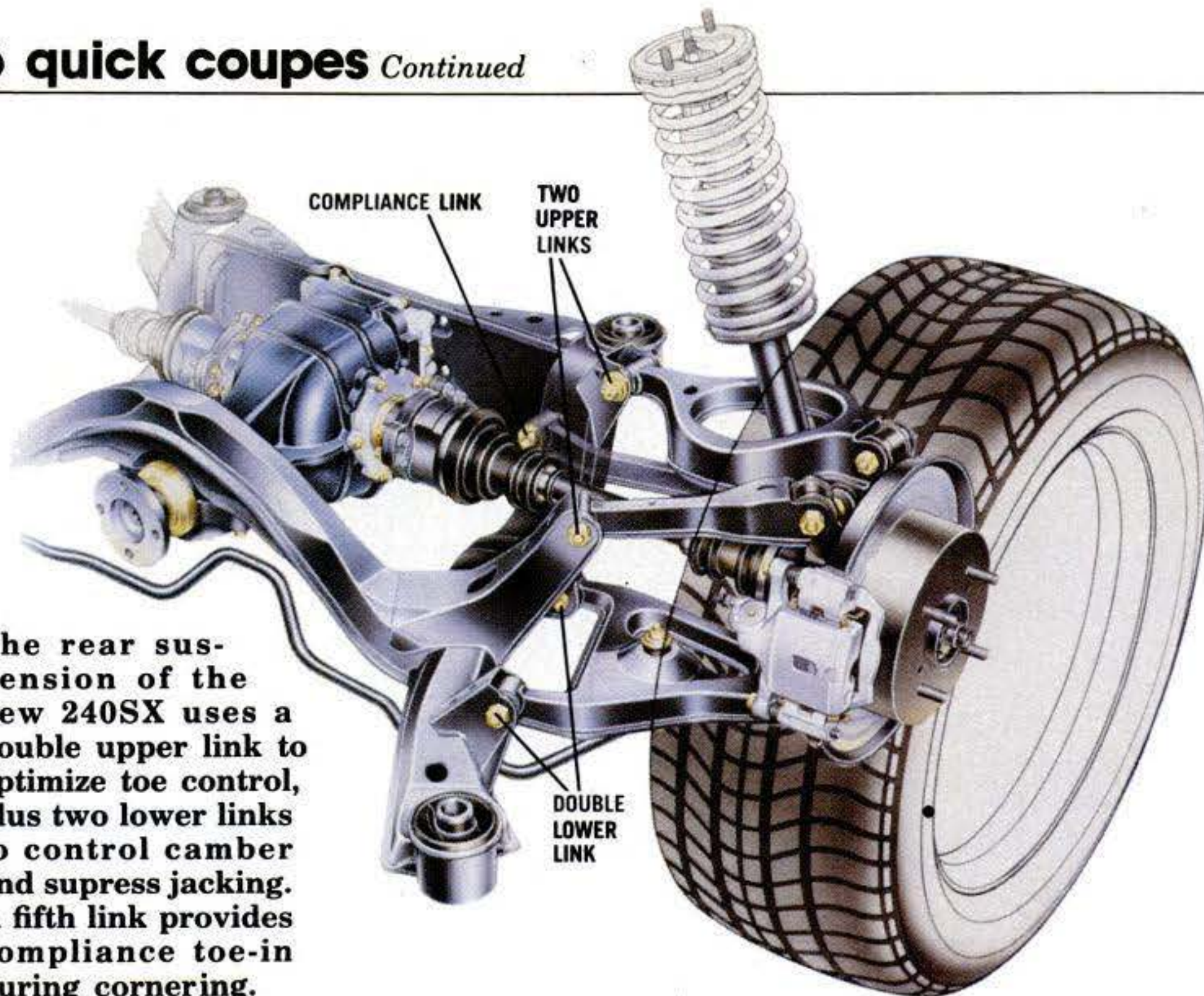
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6 quick coupes *Continued*



The rear suspension of the new 240SX uses a double upper link to optimize toe control, plus two lower links to control camber and suppress jacking. A fifth link provides compliance toe-in during cornering.

sway bar, and some other fine tuning, all of which give it a more solid, progressive feel than the Mazda. As a result, we clocked even quicker times through the high-speed run with the Probe—over 72 mph. Aside from the faster passes, the Probe rolled less and was more stable, more predictable, and less limited by understeer than the Mazda version.

But as good as the Probe was, it didn't clock the fastest time through the pylons. That honor went to the Chevy Beretta GTU. The Chevy's 16-inch low-profile tires, combined with suspension tweaks, made this one of the grippiest cars POPULAR SCIENCE has ever tested. Aside from running through the high-speed set in excess of 80 mph, the Beretta was well-mannered and generally acted as if the track were flypaper. Unfortunately, numb steering with little feedback made this a think-before-you-steer car. And the same stiff springs that performed so well on the test course outlined every pothole on the highway. Likewise, the Dodge Daytona—which turned in a 69.8-mph run through the high-speed cones with good control—turned out to be a crashing, teeth-chattering bore on rough highway surfaces.

2½ out of 3

By the time we got to the Toyota Celica, the bench mark in this test, we'd begun to think that suspension and handling were the key to defining the character of these cars. The trick seemed to be to retain some degree of ride comfort and quick, precise steering and still keep the sports-car agility when it counted.

The Toyota scored on two and a half

of these counts. The car has a suppleness that makes it one of the best road cars in the group. In the high-speed workouts it was quick enough, exceeding 70 mph in the lane change. But the Toyota has a nasty habit of getting its rear end loose when the throttle is lifted—an unnerving characteristic for a car designed to be driven quickly.

Finally, in a field of cars generally at the upper reaches of handling, the biggest surprise of all was the 240SX. Nissans POPULAR SCIENCE has tested in the past have been worse tail-waggers than even Toyotas. The 240SX, however, proved to be quick, stable, positive, and comfortable.

As the only rear-drive car in the group, the Nissan also has the most sophisticated suspension. The rear axle is a five-link layout, mounted to an isolated subframe that also carries the differential housing. The five links independently control camber, scuff, jacking, and tail lift; and the geometry gives the same compliance toe-in while cornering that the Mazda achieves with its asymmetrical bushings. Nissan thus brings the kind of engineering sophistication to a mid-priced sporty car that used to be reserved for a handful of exclusive, high-priced European models—notably the Porsche 928.

The test car, a pre-production model, was rough around the edges, but produced a 73-mph-plus high-speed lane change, 143-foot stopping distances, and subjectively the best overall handling in the group.

Suspension design has a secondary effect on the feel of these cars. Aside from handling differences, suspension mounts and low engine placement allowed lower hood lines on the Probe/

MX-6, Celica, and 240SX, which left the Beretta and Daytona—and their nose-high cowl heights—standing tall. Some drivers actually prefer riding low in the saddle, but high hood lines leave me feeling as if I'm driving a tank.

Interior treatment also set the cars apart. The Probe has an instrument pod that moves along with the steering column adjustment, a neat feature. The Beretta has seats that might be better off on your patio, while the Daytona offers the driver a multi-adjustable leather-covered throne and leaves the passenger squirming.

The Nissan featured seats made with a new technology that allows a single-piece covering with no seams. We liked the high-tech look and gave them solid marks for support as well. This car is also one of several coming this fall with so-called "heads-up display"—a system of reflecting the speedometer numbers off the windshield in the line of sight. Our test car lacked the optional feature, however.

And the winner is...

Picking an overall champion was extremely difficult, because most of the cars stood out in one area or another. Nissan's latest effort is as good an overall sports-handling package as we've driven, including some high-priced European models. The car is a bit cramped inside, and it's on the weak side in power, but it represents a new generation of engineering at a company that has been slipping for the past few years.

The Chevy and Dodge share some of the same shortcomings—a basic harshness only partially offset by excellent performance in specific areas: the Beretta's cornering power and the Daytona's acceleration and braking. Neither has the overall balance of a good sporty car, but they offer a lot of pizzazz for the money.

The Toyota, the original bench mark in this class, is still one of the best finished and most pleasant of the test group to drive in day-to-day use. However, the tricky handling and sluggish acceleration keep the coupe from competing successfully in most performance categories.

That leaves the dynamic duo, the Mazda/Ford derivatives. The improvements Ford made in the suspension are right on the mark, tweaking extremely good handling from an already good chassis; likewise the Ford-designed styling and interior, which lend an air of substance to the car. The Probe would be our first choice of the group, unless we could convince ourselves that the Nissan's lack of utility didn't really matter.

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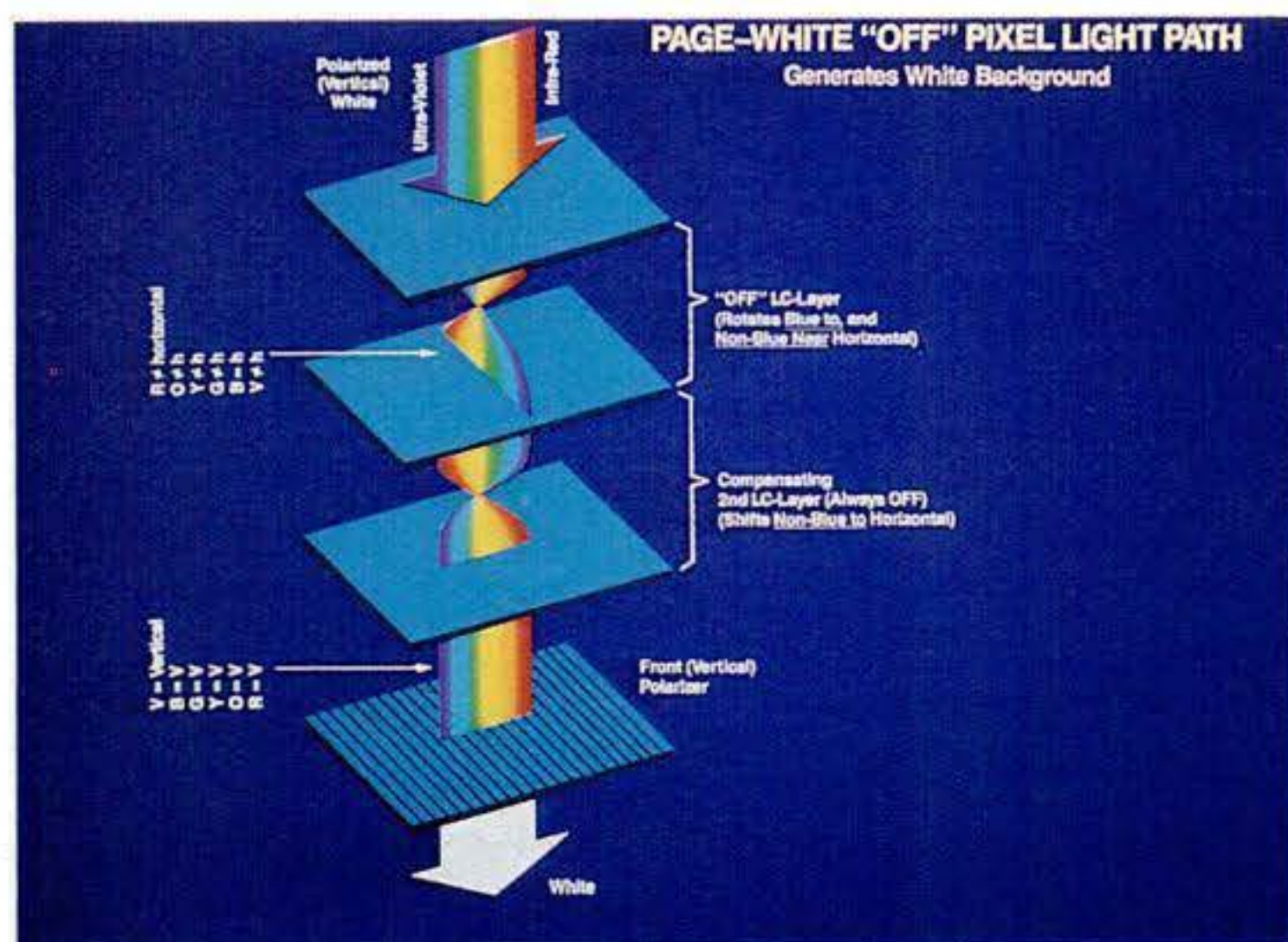
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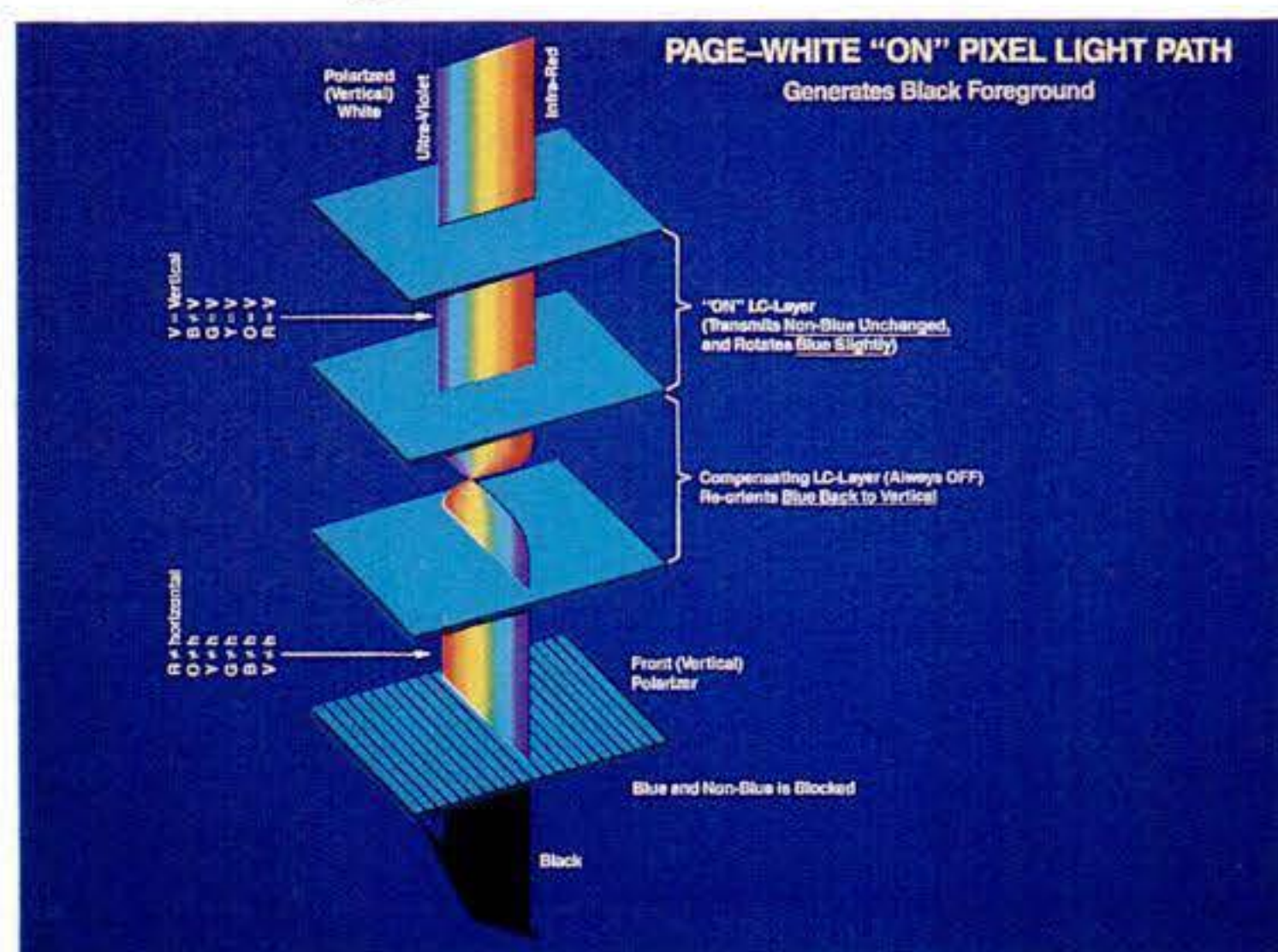
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Potent PC portable



Losing the blues: The top two LCD layers and bottom polarizer are present in conventional supertwisted LCD displays, which allow some blue to pass. The additional compensating layer repolarizes the light to eliminate the blue tint.



Its LCD display is as clear—and as white—as a cathode-ray tube. It's got 80386-microprocessor horsepower. And a new power-conservation system gives it triple the normal battery life. A powerful portable? More. It beats most desk-top machines too.

By WILLIAM J. HAWKINS

Canisters of gas spew wafts of smoke, making the crowd of people I see become mere shadows of moving light. Suddenly a half dozen men and women in black jump suits swarm from the corners of the New York ballroom and leap onto the stage in front of me. Terrorists? No.

"It's called the TurbosPort 386," says John P. Frank, president of Zenith Data Systems, now joining the black-suited people on stage who are there simply to get our attention. (They did.) Frank points to a small briefcaselike computer at center stage. "It's an 80386 portable with a full-size Page White LCD display," he says.

The screens of text and graphics I see are incredibly clear. The reason:

"The LCD display has a twenty-to-one contrast ratio," Frank says. The contrast ratio—the difference between light and dark—is comparable to a conventional monochrome cathode-ray tube and beats the highest 18:1 ratio of a gas-plasma display or the 12:1 ratio of Zenith's earlier Z-181 model.

The new display's secret is a compensating layer of material added to the layers of supertwisted liquid crystal (see drawing). The new layer removes the blue tint from the rear fluorescent backlighting, producing black images (instead of blue) on a white background. "The result is darker darks," says Frank.

I was also surprised to see how quickly the screen reacted. For example, when I asked for a disk directory using the MS-DOS "dir" command, the dis-

play scrolled clearly to view—like a CRT screen—with none of the slight blurring typical of LCD displays.

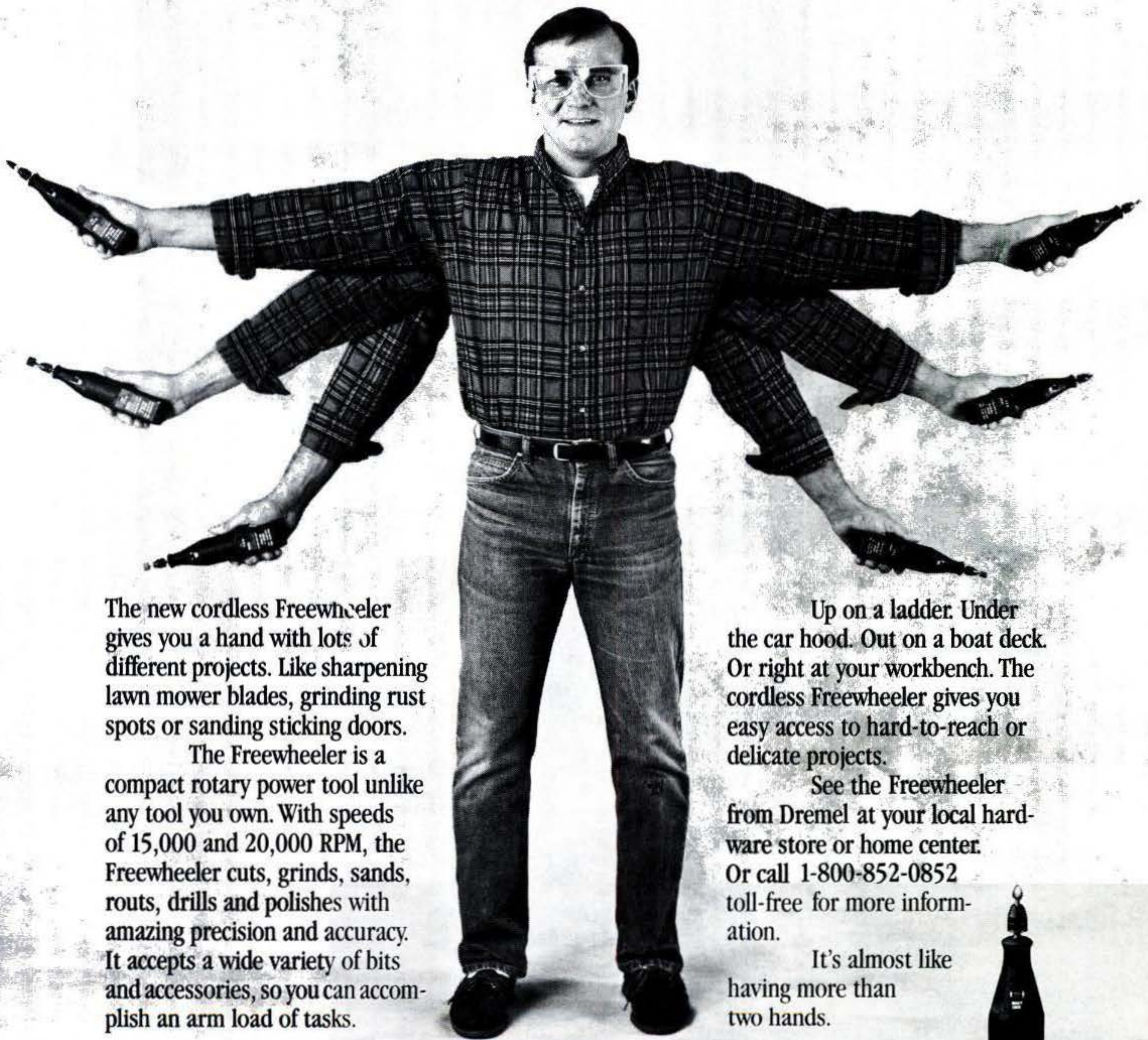
The TurbosPort, like any computer that uses the high-speed Intel 80386 microprocessor, is fast. But Zenith gives the 12-megahertz computer even more zip by using zero-wait-state memory chips for the machine's two megabytes of RAM. (Older one- or two-wait-state memory devices make the microprocessor wait one or two cycles while data are saved or retrieved.)

Included with the 18-pound (a bit heavy) portable is a 40-megabyte hard disk, a 1.44-megabyte 3.5-inch floppy, and a special power control circuit to make the battery-powered portable run for hours on a single two-hour charge. The TurbosPort 386 costs \$7,999.

P 5

The New Cordless Freewheeler™

Gives a hand wherever you need it.



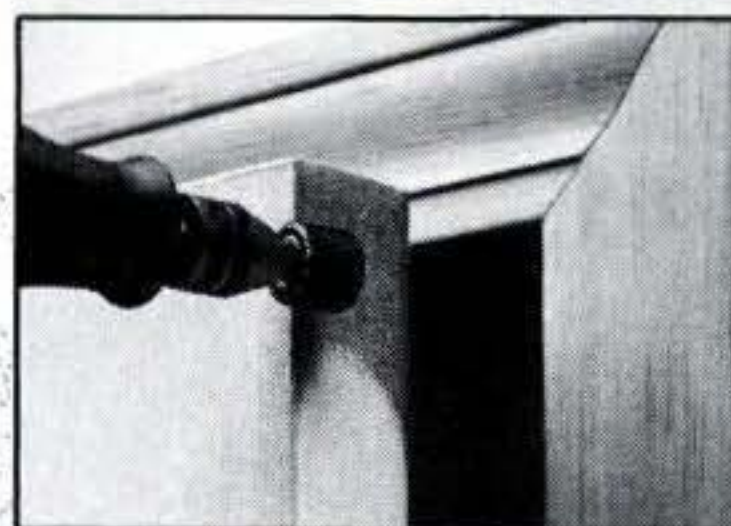
The new cordless Freewheeler gives you a hand with lots of different projects. Like sharpening lawn mower blades, grinding rust spots or sanding sticking doors.

The Freewheeler is a compact rotary power tool unlike any tool you own. With speeds of 15,000 and 20,000 RPM, the Freewheeler cuts, grinds, sands, routs, drills and polishes with amazing precision and accuracy. It accepts a wide variety of bits and accessories, so you can accomplish an arm load of tasks.

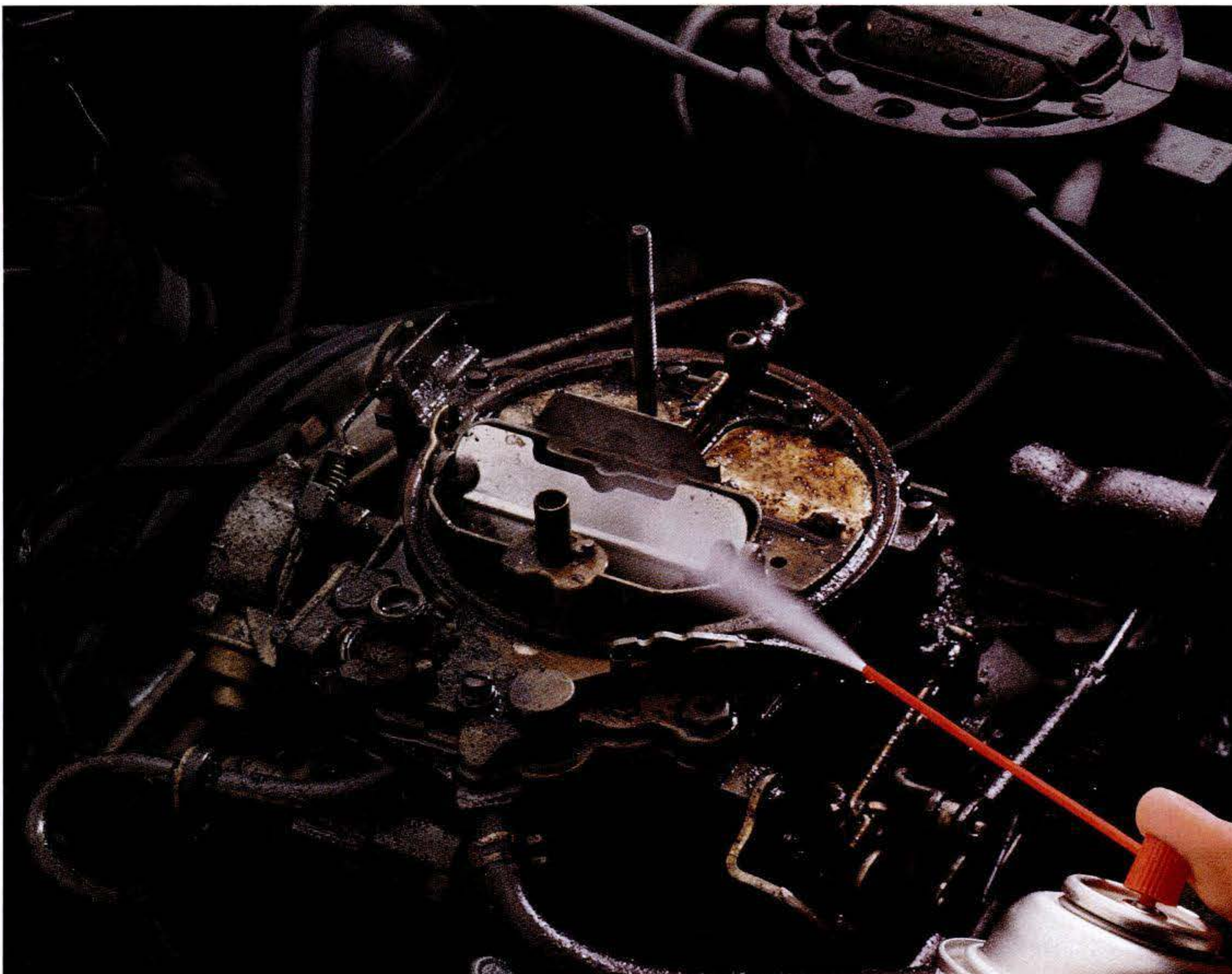
Up on a ladder. Under the car hood. Out on a boat deck. Or right at your workbench. The cordless Freewheeler gives you easy access to hard-to-reach or delicate projects.

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A close-up photograph of a carburetor assembly. A hand is holding a spray can of Jet-Spray Gumout, with the nozzle directed at the carburetor. A fine mist of the cleaner is being sprayed into the carburetor's internal passages. The carburetor itself is dark and shows signs of wear and dirt buildup.

SPRAY ON THE POWER.

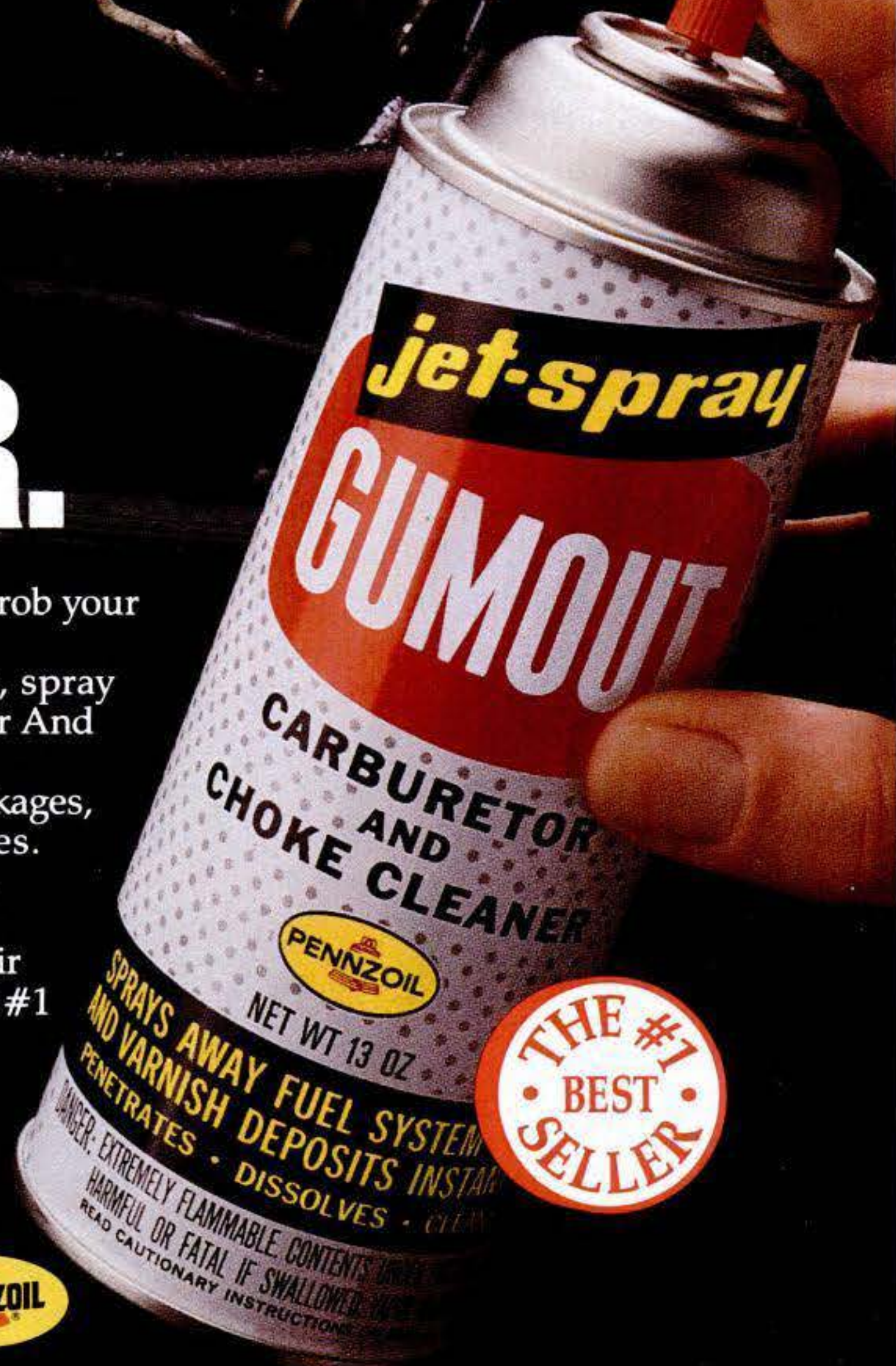
A dirty carburetor, choke, or linkage can rob your car of some great performances.

So before the power goes out of *your* car, spray on the power of Jet-Spray Gumout® Carburetor And Choke Cleaner.

Jet-Spray will wipe out dirt build-up on linkages, and in your carburetor, choke, and PCV valves. Putting a stop to rough idling, hard starting, stalling, and loss of pep.

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So if you expect great performances out of your car, spray on the power. The power of Jet-Spray Gumout®.



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What's News

Sunspace

What's the most desirable home improvement these days? Most people, if you ask them, will agree: a sunspace. It can be a pleasant place to sit and talk and grow flowers and plants during the winter. If you plan it right, it can contribute to home heating.

To meet the growing demand, manufacturers have produced many different styles, sizes, and types of sunspaces. And they've marketed a lot of accessories to make them even more comfortable and convenient. A special section in this issue will bring you up to date on the latest in the field.

Smart rocks

You can't say "Star Wars" these days without also pinning on the adjective "controversial." And that term certainly applies to the device discussed in this issue: the kinetic-energy weapon that would literally ram a missile soon after launch and destroy it by impact alone. The program, once envisioned as the first part of the program to go on operational status, has now picked up a lot of opposition based on feasibility, cost, and several other considerations.

Nevertheless, it remains a fascinating concept. The article on the following pages tells you about both sides of the picture and reveals many of the interesting details about these—well, there's no other word to use—controversial weapons.

Speedy Sunraycer

Sunraycer, the General Motors solar-powered car featured on the November POPULAR SCIENCE cover, last year won the cross-Australia race for which it was designed and built. But since then it's been breaking even more records. In September 1987 a Chevrolet car development engineer named Molly Brennan drove the Sunraycer around the five-mile track at GM's Desert Proving Ground in Mesa, Ariz., at a speed of 35.22 mph. In June she smashed that record, upping the speed to 48.712 mph.

The car ran on solar power alone; no batteries were aboard. The Magnetoquench motor ["Mighty Magnet," Feb. '85] that powers Sunraycer weighs only 11 pounds, but produces an amazing two horsepower at 4,000 rpm—30 to 40 percent more power than commercially available motors of a similar size. Power comes from 8,800 gallium arsenide and silicon solar cells.

The remarkable Mr. Rutan

POPULAR SCIENCE has covered the work of Burt Rutan many times, featuring his work on four covers over the last 10 years. But I was surprised to find that he is mentioned in this issue three times in connection with three different projects.

First comes a major piece on a new Rutan airplane—the tandem-wing transport. His name crops up again in the piece about the America's Cup competition; he built the unorthodox wing sail used on the U.S. boat. Finally, the "What's New" section pictures a new propeller-driven racer that took shape first in the Rutan mind.

We didn't plan all this coverage; it just happened because so many fertile ideas come out of the Rutan operation. That's a tribute to the ingenuity, inventiveness, and energy of the country's best-known aerodynamicist.

Let's hear it for hype

One of the most elaborate retirement parties in memory took place on the July 4th weekend. What made the event noteworthy was not so much that it lasted for days; had the state governor as guest of honor; had a new ice cream and a new beer named in honor of the retiree; and that the three-day celebration included dancing, a parachute-jumping exhibition, concerts each night, a huge dinner, tours, and fireworks.

No, it wasn't the event itself; it was that all of this went on to honor the retirement of a wood stove. Vermont Castings launched its Defiant wood stove in the mid-'70s—when the energy shortage suddenly made wood stoves popular. The 12-year-old stove

is, according to Vermont Castings, "credited with revolutionizing the industry." But now new EPA wood-stove emissions regulations are going into effect. The Defiant would not be in compliance, so it is being retired.

Says company chairman Duncan Syme: "We would not be doing justice to the Defiant with a typical quiet retirement. We've planned a retirement party with the affection and respect equal to that given a great athlete whose number is being retired."

Hmmm.

Big-bucks bomber

The stealth bomber [July] will—surprise!—cost more than predicted by early estimates. When the program was first announced in 1981, the cost of a 132-plane fleet was put at \$36.6 billion—\$277 million each. Inflation took that number up to \$57.2 billion. But the General Accounting Office now says a more realistic number is \$68.8 billion—\$520 million each.

Big antenna in the sky

The U.S. Navy communicates with submarines with a low-frequency radio signal transmitted by a huge buried antenna in Wisconsin. But there has been much opposition. Residents fear that the powerful signals may be harmful to people and wildlife. Now a new technique may make the big antenna unnecessary. Pennsylvania State University professor Anthony J. Ferraro aimed a one-megawatt radio beam into the sky above Fairbanks, Alaska. This heated the charged particles of the ionosphere 30 to 60 miles above the surface of Earth, turning them into an antenna that could reflect low-frequency signals efficiently. The work is funded by the Office of Naval Research.



Editor-in-Chief

MISSILE

Proponents of the Pentagon's Strategic Defense Initiative say satellite-launched projectiles could knock out most nuclear missiles before they reach their targets. But some experts feel this element of the "Star Wars" program is overpriced and unworkable. The practicality of this complex technology may not become clear for a decade or more.

By JIM SCHEFTER

Illustrations by Dennis M. Davidson

Defcon one! Defcon one!"
"Arm the platforms."
"Platforms armed. Scanners active. We have eighty-four in the envelope."

"They're launching! Bad guys in all sectors... Beast says launches are confirmed."

"Turn 'em loose! Twenty more platforms coming over the horizon. They'll try for the strays."

Six hundred miles up, dotting the black sky from horizon to horizon above Soviet intercontinental missile fields, 84 U.S. satellites—space-based interceptor platforms—prepare to disgorge their loads of five-foot-long missile killers.

Data streaming down from a geostationary boost surveillance and tracking satellite (BSTS, or "beast") feed target coordinates and trajectories to each platform's battle-management computer. Seconds later, with climbing Soviet missiles in their sights, the interceptors fire their small and extraordinarily powerful rocket engines.

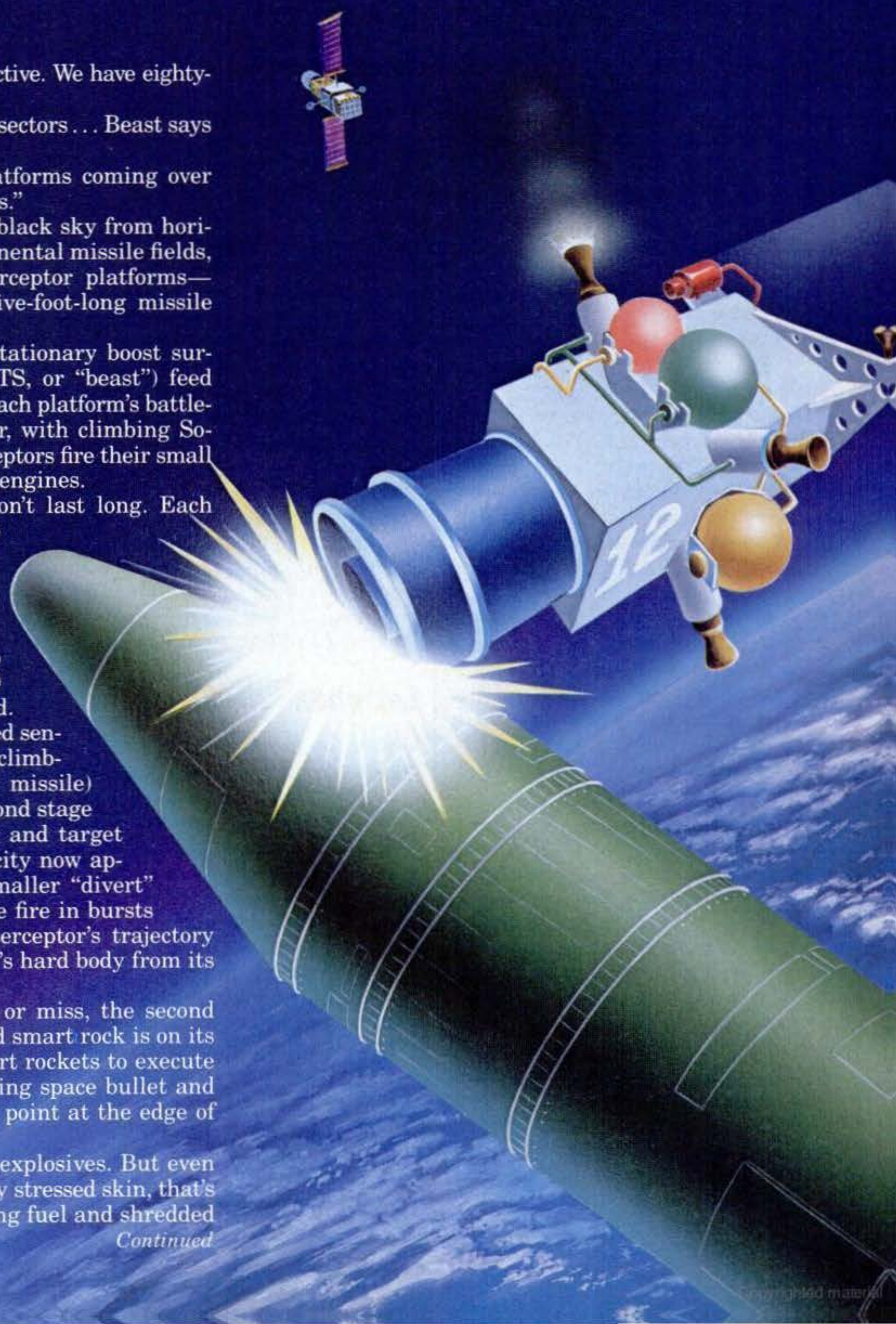
Now the chase is underway. It won't last long. Each interceptor is a multi-stage missile topped by a "smart rock," or kinetic-kill vehicle. Accelerating to incredible speeds—the numbers are classified, but the first stage probably goes from zero relative velocity to more than 6,000 mph in under 30 seconds—the missiles race downward.

Centered in an interceptor's advanced sensor eyes, the fiery exhaust plume of a climbing ICBM (intercontinental ballistic missile) glows intensely. The interceptor's second stage kicks in and the gap between killer and target shrinks dramatically as closing velocity now approaches seven miles per second. Smaller "divert" rockets bristling from the kill vehicle fire in bursts like machine guns, nudging the interceptor's trajectory as its sensors discriminate the target's hard body from its plume.

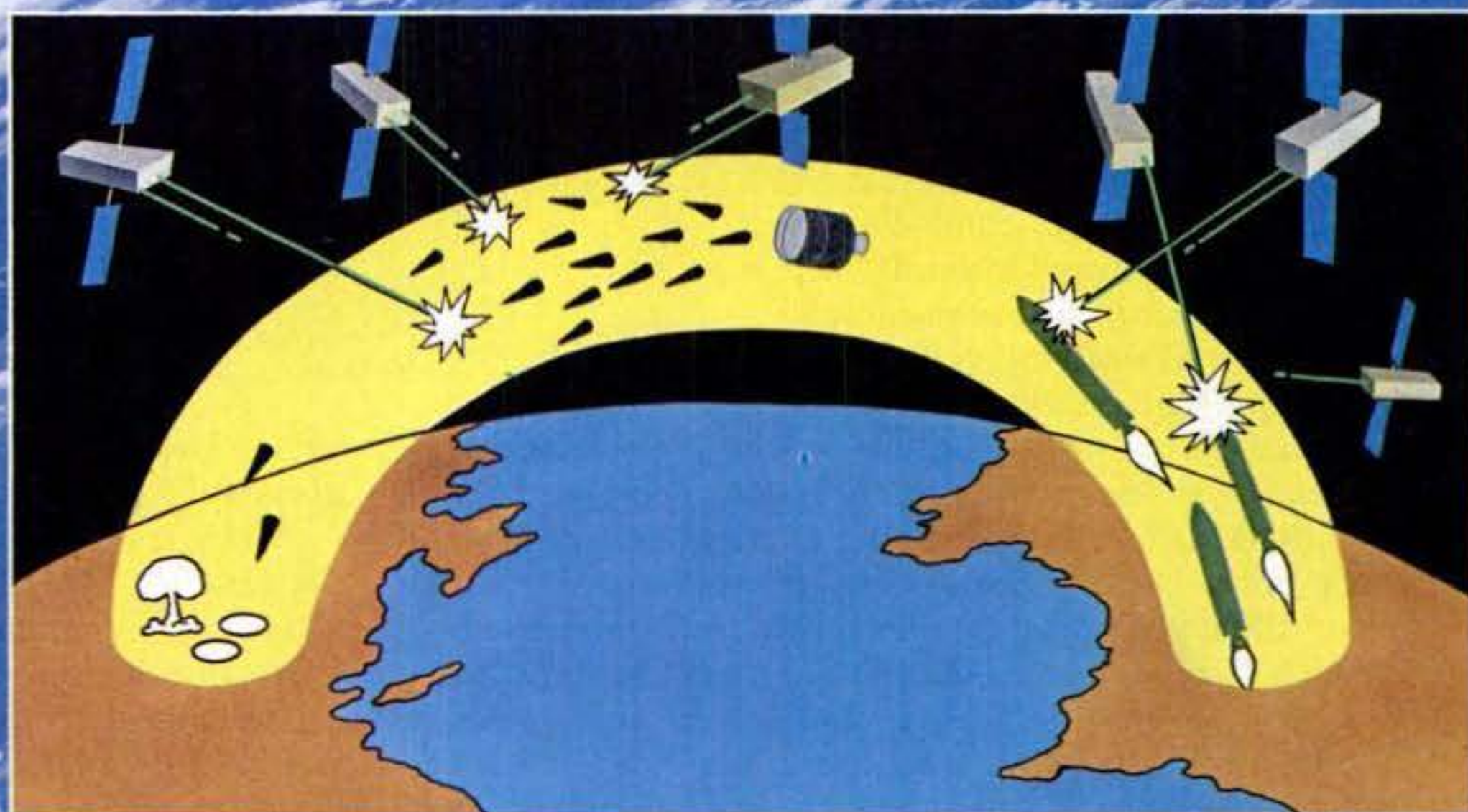
With only moments left until hit or miss, the second stage separates, and the oddly shaped smart rock is on its own. There's barely time for the divert rockets to execute their final corrections before the diving space bullet and the climbing ICBM reach a common point at the edge of the atmosphere. Then it's over.

The kinetic-kill vehicle carries no explosives. But even if it only grazes an ICBM's thin, highly stressed skin, that's more than enough. A rage of exploding fuel and shredded

Continued



KILLERS



The SDI program aims to defeat ICBMs by several means. Laser and particle-beam weapons and electromagnetic rail guns are some of the systems now being developed in research laboratories. The scenario above depicts the SDI element that is nearest to being built and put into service—a space-based missile-interceptor system. Here's how it's designed to work: When hostile ICBMs are launched, scores of sensor-equipped orbiting platforms detect the fiery plumes emitted by their rocket engines. Each platform disgorges a flock of small rocket-propelled interceptor craft that home in on the climbing missiles. As an interceptor approaches

a target, its rocket-booster stage separates, leaving only a kinetic-kill "smart rock" to pursue the ICBM. The interceptor's nonexplosive warhead uses small "divert" rockets to fine tune its trajectory toward a devastating collision with the missile. ICBMs that survived attack by interceptors during their first few minutes of flight would be attacked by a second wave of interceptors launched from platforms maneuvered to catch the missiles' multiple warheads during their mid-flight phase. Other SDI elements would be required to deal with the estimated 10% of the warheads the system's designers predict would elude the interceptors.

DAVIDSON 1988

metal blossoms in the thin atmosphere high over Soviet territory. Among the debris, undetonated nuclear warheads tumble back to Earth. Elapsed time since the war began: four minutes.

But some ICBMs have escaped and released their nuclear-warhead reentry vehicles. In the next four minutes more interceptor platforms come into range and attempt to engage those individual warheads coasting through their mid-course phase on the way to the continental United States. If the system works as planned most of them do their jobs. But even the most optimistic supporters of the interceptor program assume that about 10 percent of the nuclear weapons would elude the interceptors and need to be tackled by other Strategic Defense Initiative (SDI) systems.

Missile shield or pipe dream?

Is this scenario wishful thinking? Something dreamed up by the Reagan administration and the aerospace industry to funnel more than \$550 million worth of research into an impractical element of SDI?

Or are space-based interceptors a realistic possibility—an anti-missile system that might prevent most Soviet nuclear warheads from hitting U.S. cities if the nation ever gets to the war-alert status of defense condition (defcon) one? If they are, interceptors could become the earliest operational phase of SDI, while research and development continues on other systems. These include laser and particle-beam weapons and last-ditch high-energy missiles aimed at warheads that slipped through the net.

To find out, I talked with SDI officials in their basement headquarters at the Pentagon, and with engineers at the Martin Marietta Corp. near Denver and at Rockwell International Corp. in Southern California, where competing designs for kinetic-kill vehicles are taking shape. The program is a costly one, regardless of whose numbers you accept. Rockwell estimates the system's 10-year operational cost at \$20 billion, while *Aviation Week & Space Technology* reports the U.S. Air Force thinks it will cost \$80 billion.

I also talked with leading SDI critics, who view the program with strong skepticism and say that the Pentagon's push to deploy missile interceptors by the mid-1990s is the wrong way to go. One surprising fact emerged: If the system never has to be built—because the mere threat of its existence is enough to help negotiate appropriate peace treaties—everyone (including the contractors, who would rather explore space than fight in it) will be happy.

"The job of the American military is not to win wars, but to prevent them," said Lt. Gen. James A. Abrahamson, director of SDI, at a press briefing last year in Los Angeles. "But right now we can't stop one incoming missile. Not one." That makes space-based interceptors key power pieces in the ongoing strategic chess game. Behind closed doors and with no advance notice, the United States moved anti-missile weapons onto the playing board during last December's Washington summit meeting. Less than 48 hours before Marshal Sergei Akhromeyev, chief of the Soviet general staff, made an unprecedented visit to the Pentagon, Abrahamson asked Rockwell and Martin Marietta to rush their full-scale interceptor models to the capital.

No mention of the models was made in briefings to re-

porters, but they were in prominent view during Akhromeyev's private meetings with Defense Secretary Frank Carlucci and Adm. William J. Crowe, chairman of the U.S. Joint Chiefs of Staff. The marshal's reaction? "He just stared at them," a Pentagon spokesman told me. "He didn't say a thing." But he probably got the message.

Even so, if missile interceptors are to serve as an effective bargaining chip, they must be real. A little-known SDI test in space in September 1986 gave Abrahamson and his team the confidence to bet more than half a billion dollars that they can work.

In that test SDI launched a specially modified and instrumented Delta rocket into low orbit. The Delta's second and third stages separated and then moved nearly 140 miles apart. Both stages carried packages of sensors taken from operational weapons systems.

As the stages crossed the Pacific, controllers turned them to face each other, then fired their main engines. One stage mimicked an enemy ICBM. The other played the role of kinetic killer, picking up the rocket flare in a sensor eye from a Phoenix missile. Jinking and jogging through space, it intercepted the accelerating stage in the night sky over Kwajalein Atoll. The high-speed collision shredded both stages. For SDI, the spectacular explosion proved to be a promising demonstration.

It also was enough to prove to Abrahamson, if not to SDI's vocal critics, that intercepting a rocket in space was possible. But an operational system would be much different from the Delta test; it would have as many as 300 platforms in orbit, each containing 10 to 20 miniature interceptors. That would be a complex undertaking that some say would still not be up to the task. For example, a recent study by Lawrence Livermore National Laboratory concluded that about 100,000 orbiting interceptors would be required to destroy 90 percent of the 14,000 strategic nuclear warheads the

Soviet Union is expected to be capable of launching in a massive strike in the mid-1990s.

"We're trying to do something in space that's never been done before," said Lloyd Stoessell, manager of space-based kinetic-kill vehicles at SDI's Pentagon headquarters. The large number of platforms, he explained, is needed because of orbital dynamics. Only one-third or so of them would be in an imaginary "envelope" over Soviet missile fields at any moment. Others would be on the way, but that's not good enough when ICBMs are climbing through the clouds.

Exactly nine months after the Delta test SDI issued matching four-year \$150-million contracts to industry teams headed by Martin Marietta and Rockwell to develop interceptor systems. Rockwell got an additional \$250 million to stage a flight test from Kwajalein late next year. It will launch a test-bed vehicle loaded with newly developed sensors, then turn it around to intercept a second rocket during its boost phase.

Yet another space test was launched last February atop a Delta rocket. It carried a mixed payload of sensors, decoys, and simulated Soviet missiles. The mission gathered information on what warheads might look like after separating from their ICBM booster. Much of that data will be used for SDI elements that would attempt to knock

Continued

“The system would have as many as 300 orbiting platforms, each containing 10 to 20 interceptors”



PHOTO: ROCKWELL INTERNATIONAL CORP.

The two-and-a-half-stage space-based interceptor design at left was developed by Rockwell International Corp. The "doughnut" structures are toroidal fuel tanks, which feed a rocket engine hidden beneath the lower two rings. About one minute after the engine fires, the exhausted lower rings drop off, exposing the engine, which continues to draw fuel from the next two rings. Then they drop off, leaving only the kinetic-kill vehicle with a small ring wrapped around its middle supplying fuel to four divert thrusters. Martin Marietta Corp.'s interceptor (below) is a three-stage craft. Stage one (at right in photo) consists of a rocket motor and black-colored fuel tank. The second stage uses a smaller rocket fueled from the colored spherical tanks. The third stage is the boxy kinetic-kill vehicle with its forward-facing target sensor; spherical fuel tanks also fuel its thrusters.

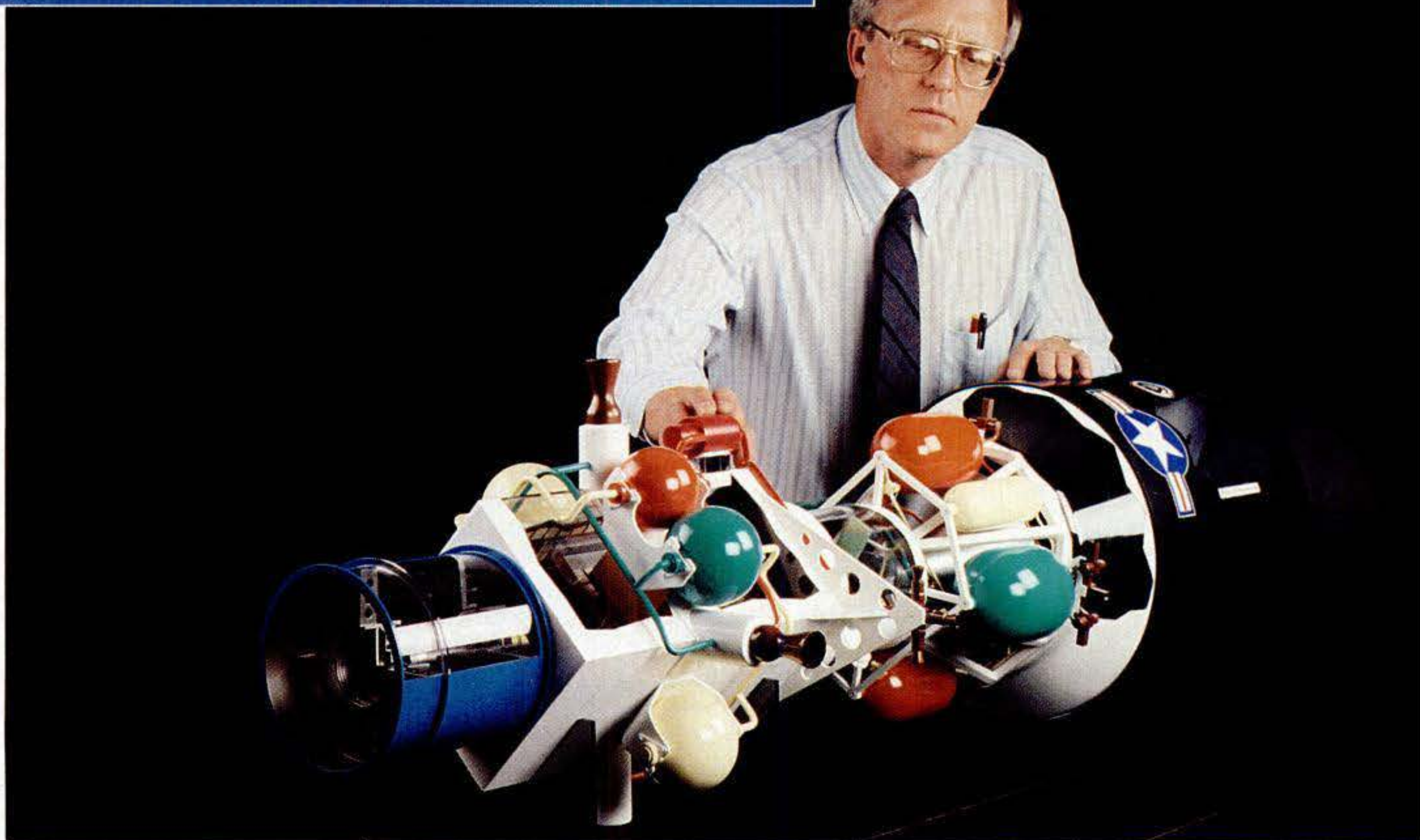


PHOTO: MARTIN MARIETTA CORP.

out targets that the interceptors missed. Some of the sensors tracked the plumes of rockets launched during the test, while others gathered background readings on both Earth and sky. That information would feed directly into the space-based interceptor system.

These tests have not been popular with SDI critics. "When you commit prematurely to large demonstrations in space you distort the research program," said accelerator physicist Dr. Sidney Drell, co-director of Stanford University's Center for International Security and Arms Control. "You freeze the design too soon. Big demonstrations carried out prematurely are good for public relations, but are not good for a research program."

SDI insiders disagree. The space tests are a vital part of their research, they say, providing data that can't be simulated accurately in the laboratory.

Drell is not opposed to SDI's long-range goal. "We need a serious research program to determine if it is even feasible," he told me. "But I'm worried about the trend that's concentrating more on near-term deployment than long-term technologies. SDI should be a balanced program."

SDI spokesmen counter by saying that the threat of early deployment of interceptors is enough to force the Soviets to negotiate seriously and already has led to significant arms reductions. Of all the SDI elements being considered, only the interceptors have the potential for early deployment.

"There are two pieces to the system," Stoessell told me. "First there are the satellite platforms. Each will have a fixed number of interceptors, communications equipment, power, something to deal with the heat that's generated, and the ability to move around a bit in orbit. There also will be some other survivability things that are classified."

Stoessell envisions Martin Marietta and Rockwell proposing a simple solar-powered platform designed with replaceable modules for in-orbit servicing, perhaps by an automated satellite making periodic rounds. Except for its communications system and its battle-management computer and software—certain to be among the most expensive and sophisticated components—a platform's major feature would be the tubes containing interceptors.

With hundreds of identical satellites to be built and orbited, SDI managers recognize that they're asking the aerospace industry to enter a new phase: mass manufacturing. "We can't go after this like a regular satellite program where they build one or two at a time," Stoessell said.

The competing companies are taking sharply different design approaches. Both have created an oddly shaped kinetic-kill vehicle—the small ungainly smart rock that would actually hit an ICBM—with space flight in mind. Like the Apollo lunar module, which never had to fly in Earth's drag-inducing atmosphere, it doesn't need to be sleek or curvy. So each design bristles with small rockets and projections, boxy modules, and a forward-looking sensor tube—like some sort of killer space porcupine.

But Dr. Richard L. Garwin, IBM fellow at the Thomas

J. Watson Research Center, adjunct professor of physics at Columbia University, and a government consultant on defense technology since the 1950s, has little hope that either Martin Marietta or Rockwell will succeed in creating useful systems. "Anything we know how to build won't be cost effective and will be war provoking," he says. "One of the main reasons is that the interceptor platforms themselves will be vulnerable to attack."

In the Martin Marietta design the kill vehicle sits atop two miniaturized rocket stages. I looked at the full-scale model at a company facility south of Denver and marveled at its compact size—barely five feet long, 16 inches in diameter, and weighing 150 pounds.

The two-foot first stage has a 4,000-pound thrust rocket and enough solid fuel for 10 to 12 seconds of brute-force acceleration. The liquid-fueled second stage is six inches shorter but carries a 600-pound thrust rocket. Both engines, being developed by the U.S. Air Force Astronautics Laboratory in Palmdale, Calif., are physically small but have unusually high thrust-to-weight ratios that give them

faster acceleration while burning less fuel. The engines are likely to find applications in other space programs as well, both military and civilian.

The second-stage engine can be stopped then restarted after brief periods of coasting, while an on-board computer refines the intercept trajectory. When the kinetic-kill vehicle, also 18 inches long, separates for the final few seconds of track-and-smash flight, it will be traveling at a speed of several miles per second. "It hits with enough force to vaporize itself," said Martin Marietta's program director, Richard W. VandeKoppel. "There is no need for explosives."

Rockwell's interceptor package might be called "Michelin Man goes to space." It looks like a pyramid of doughnuts. "Those are toroidal fuel tanks,"

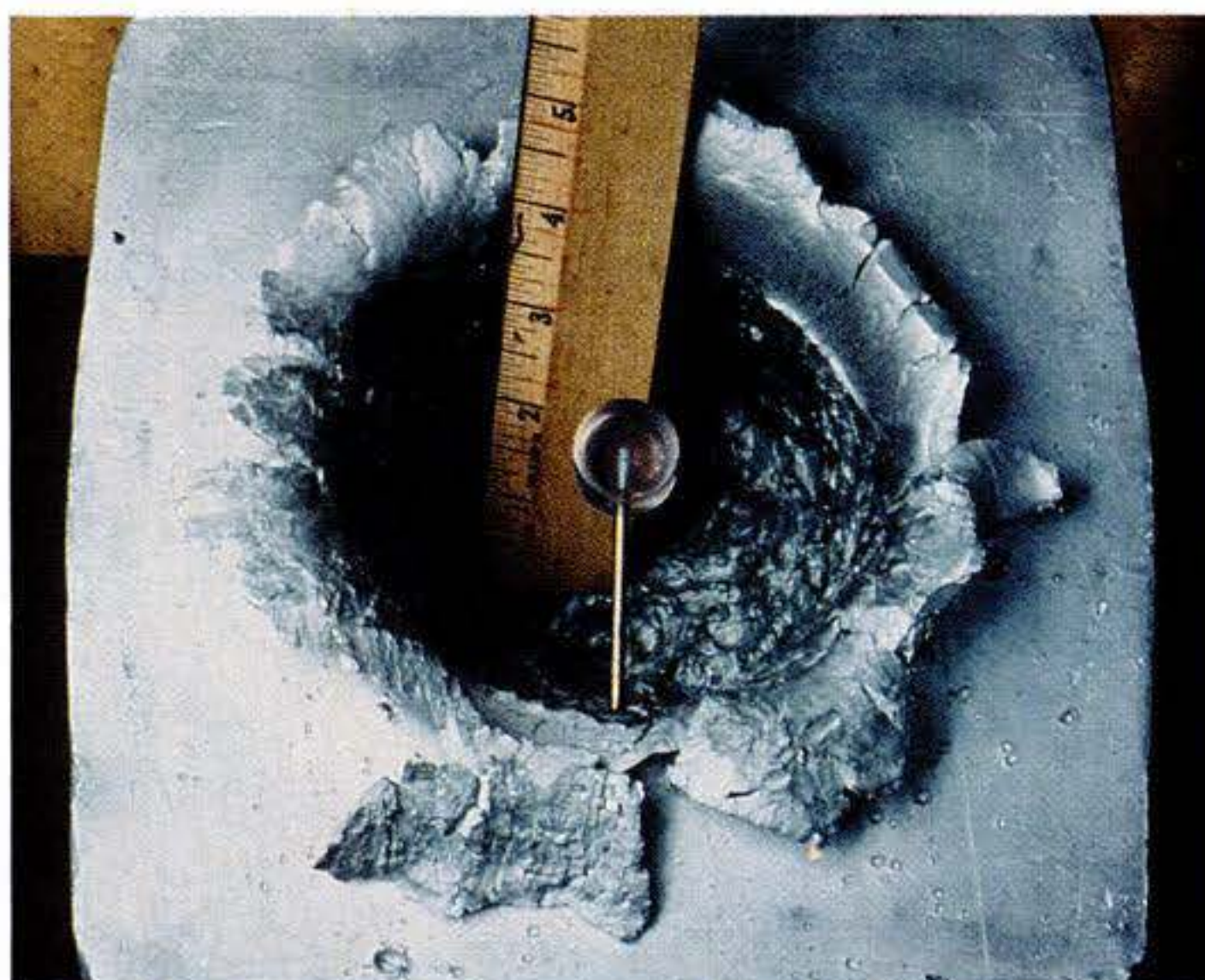
said Dr. John B. Peller, vice president and program director, as he showed me a full-scale interceptor model. "It's a stage-and-a-half vehicle, with one main engine and two sets of tanks."

Rockwell's preliminary platform design calls for stuffing the interceptors nose first into storage tubes. Interceptors would pop out backward, then spend several seconds turning around and finding targets before the main engine fired.

This engine is the same restartable rocket Martin Marietta uses in its second stage. Rockwell hides the engine inside the bottom layer of doughnuts, which are discarded when their fuel runs out. That's the half stage. Smaller doughnuts carry fuel for mid-flight operations and for the course-correcting divert engines. Barely more than a minute into its mission, this stage drops off, leaving only the kinetic-kill vehicle hurtling toward an oncoming ICBM.

One final fuel ring girdles the kinetic-kill vehicle itself. That ring has just enough fuel for the little machine's own divert engines to rapidly fire a few final corrections of its aiming point. "By that time you could have closing velocities of up to eight miles per second," Peller told me. "So your aim had better be right on."

[Continued on page 110]



A warhead doesn't always need explosives to cause severe damage. The block of aluminum above was struck by a small plastic projectile—like the one in the center of the crater—traveling at about 4 miles per second. Kinetic-kill weapons work in the same way, relying solely on ultra-high velocity for their destructive punch.

Rutan's tandem-wing transport



Aircraft engineer extraordinaire Burt Rutan has designed an unusual tandem-wing composite airplane to fill the Pentagon's need for a low-altitude long-range airlifter with short takeoff and landing capabilities. The proposed Advanced Technology Tactical Transport will ferry troops and materiel to remote unimproved airstrips and back.

By **JIM SCHEFTER**

The chilly high-desert air was wrapped in an ice-blue January sky. Rows of derelict Convair 880s squatted in the dry distance, forlorn

relics condemned to play antique audience to the day's event.

The human audience, not so antique, and a mixed bag of U.S. Air Force blue suiters, aerospace executives, airplane enthusiasts, and reporters crowded to the edge of the runway.

They leaned forward suddenly, raising cameras, binoculars, and expectations as the twin turbines of the exotic double-winged aircraft spooled up to brake-release speed.

Then the mini-transport began to
Continued



PLASTIC PLANE—Fabricated of lightweight but stiff resin-composite materials, Scaled Composites' Advanced Technology Tactical Transport (AT³)

—shown here under construction—was built and flown in less than two years by a team of about 16 engineers and shop technicians.

move. Like an Olympic hurdler charging out of the blocks and through the tape, it burst past the earthbound observers. Quick-eyed witnesses saw the extended fast-acting wing flaps deflect downward in an instant. A moment later Burt Rutan's Advanced Technology Tactical Transport (AT³) leaped into the air, pointed its tapered nose sharply up, and then banked left into a steep climbing turn.

Cheers and yells followed in the wake of its upward arc, joined by speculation that the subscale ship easily broke ground in less than the predicted 1,000-foot takeoff roll. "This is dynamic testing with the pilot in the loop," Rutan said later, after the AT³ completed a series of low-level passes, then landed and stopped in just about no distance at all. "That's the approach we take in addressing new aerodynamics."

New aerodynamics is Rutan's stock in trade. Now the reigning wizard of advanced aircraft design—his canard-based fliers include speedsters like the VariEze and Long Ez [Nov. '78; May '82], the world-circling *Voyager* [Sept. '84], and Beechcraft's Starship corporate craft [June '84]—was using his fertile imagination and skills with composite fabrication to brush aside convention with a new kind of military transport built for the Defense Advanced Research Projects Agency (DARPA).

The Pentagon sought the AT³ to fill a gap between transport helicopters and much larger C-130 fixed-wing

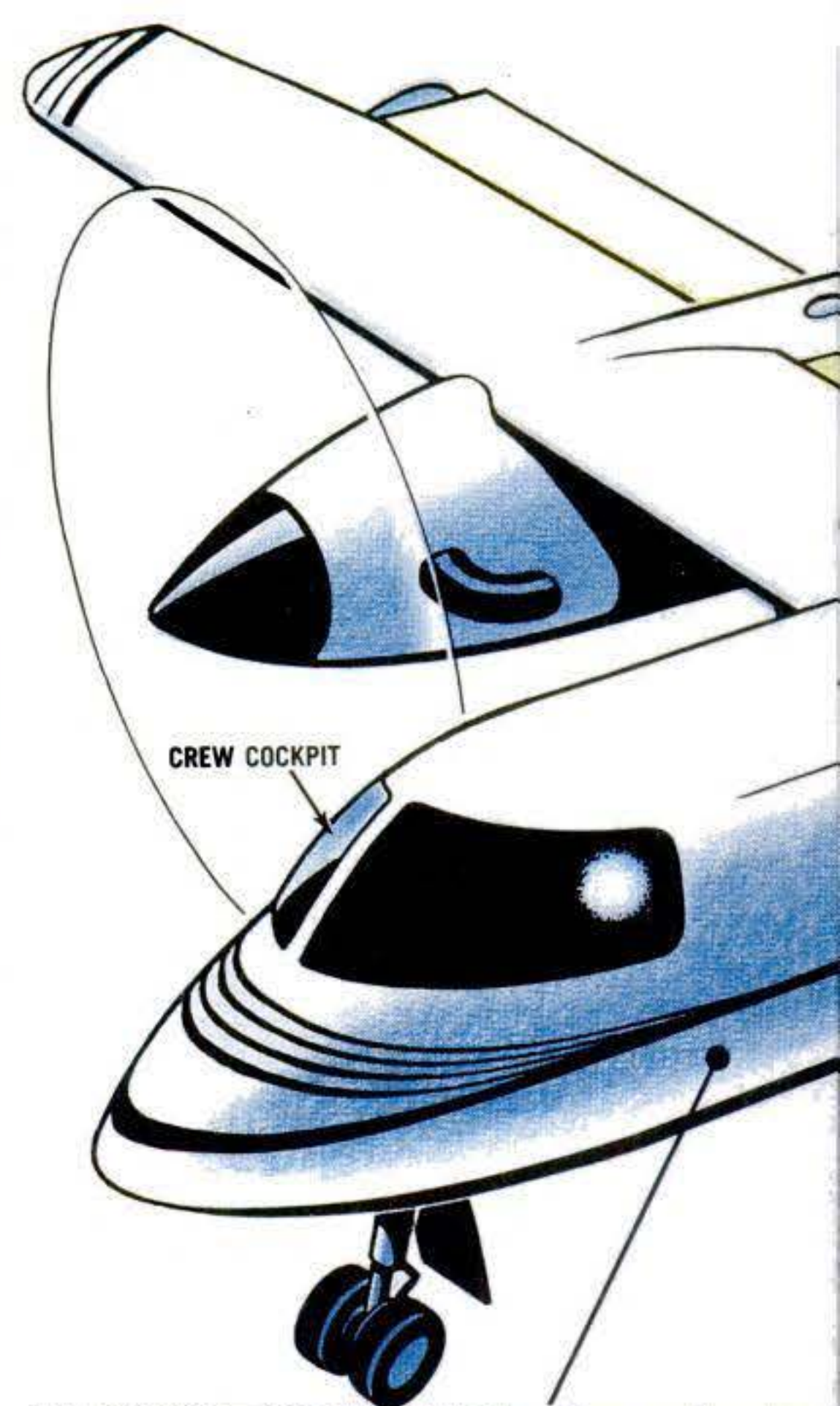
cargo planes: missions in which aircraft are required to make long-range, low-level, in-and-out excursions to deliver up to 14 troops or 5,000 pounds of cargo to remote sites with short runways. With a round-trip range of 2,400 miles and a top speed of 380 mph, it would be ideal for small-scale covert operations and rescue or resupply missions in hostile territory. Such missions now are handled by a heterogeneous fleet of C-130s, Beechcraft King Airls, and large choppers.

Bundle of innovations

"The AT³ is a bunch of little pieces of innovative design and technology that all go together," said Col. Doc Dougherty, DARPA's program manager. "It's also an experiment in prototyping. People have been saying that we need to do more of that."

In the prototyping approach to aircraft development, the Pentagon sets general guidelines for an airplane—its mission, size, approximate speed, and other factors—then lets an aerospace company design, build, and test an aircraft that meets them. It doesn't define the aircraft down to the last nut and bolt, and then ask competing contractors to submit detailed designs. The procedure was used successfully in developing the Air Force's F-16 fighter.

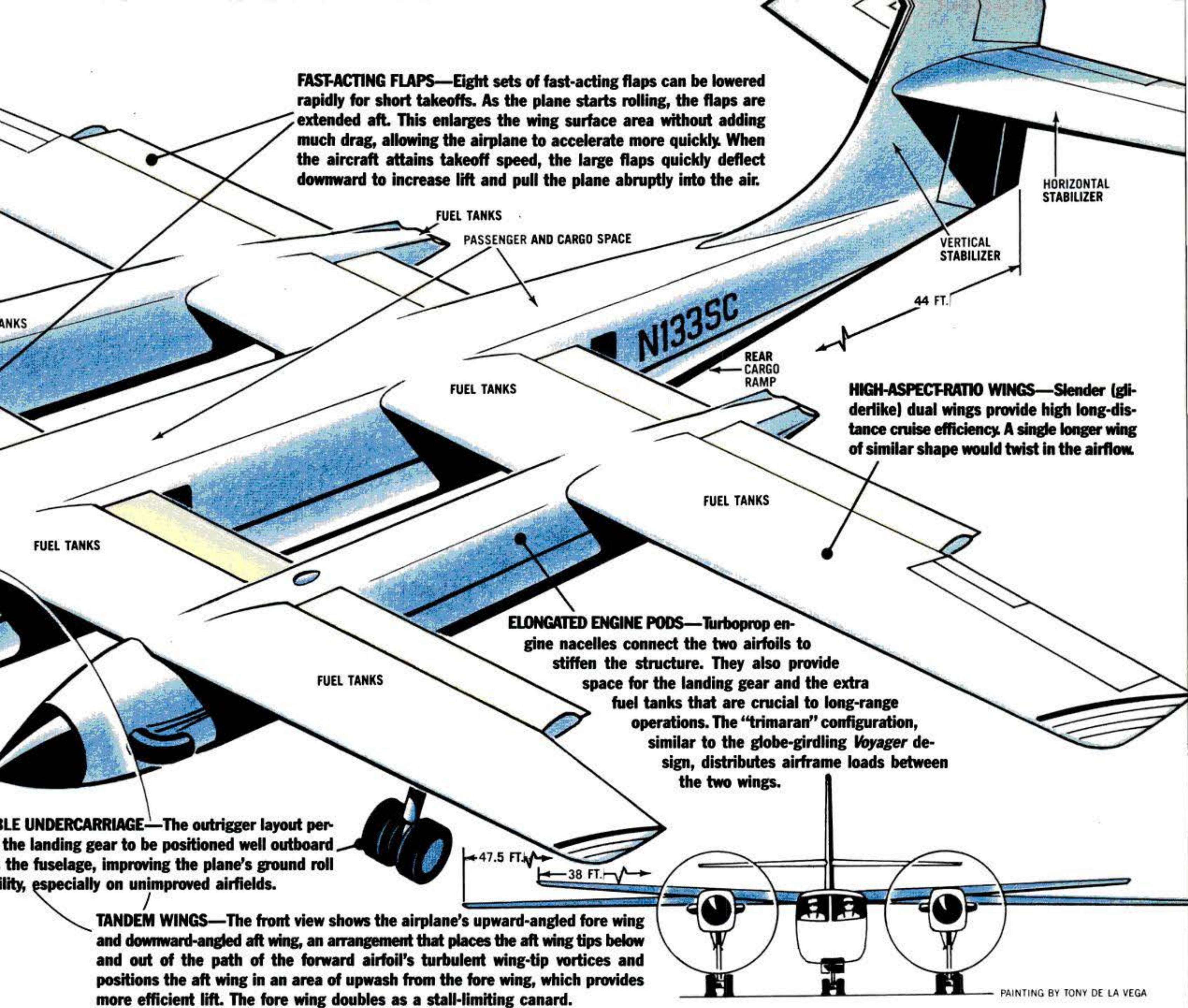
"You couldn't prototype an expensive and highly complex aircraft like the B-1 bomber," Dougherty said. "At the upper cost end, prototypes don't make a lot of sense." The reasons: Detailed design is required early on



ALL-COMPOSITE CONSTRUCTION—Glass and carbon fibers embedded in an epoxy-resin matrix make up most of the airplane's structure. Besides reducing weight, the use of composites permits the rapid reconfiguration of components during testing. Metal components would take much longer to remanufacture.

to avoid mistakes that could cause cost overruns, and coordination among many contractors on large projects is difficult. "But for lower-cost aircraft," Dougherty continued, "building a prototype or proof-of-concept airplane seems to work."

Working under a unique contract from DARPA that allowed Rutan's Scaled Composites, a subsidiary of Beech Aircraft Corp., to operate more independently than larger aerospace companies working on Pentagon projects, the small firm built and flew the AT³ in less than two years. "We did it with only about sixteen people," Rutan told me in an exclusive interview, "about one-third of them engineers and two-thirds shop people." Burdensome regulations are symptoms of a "can't do" attitude, he opined. "I want to make decisions quickly. Every day at four p.m. we all stand in a circle and decide what we're going to do in the next twenty-four hours. You'd be surprised at how fast you can move things along that way."



At even a casual glance, the AT³ is different. It’s small—built at 62 percent of full-scale design size. And it’s smooth. Rivets and skin joints are completely absent. In typical Rutan fashion, there’s very little metal in its wings or body. Instead, all major assemblies are formed from composites of glass and carbon fibers and epoxy resin. That reduces the AT³’s empty weight to less than 6,000 pounds, smoothes the airflow over its surface, and gives the structure an incredible strength.

A roundly tapered and sloped nose blends smoothly into an immense bulging windshield, which in turn curves back into the fuselage, giving the two-man flight crew extraordinary visibility. The 44-foot fuselage itself is a flattened tube that sits low to the ground.

In the style of much larger military transports, the underfuselage of the subscale craft angles up to the tail to accommodate a rear cargo ramp. The tail assembly is almost traditional,

with elevators mounted nearly halfway up the vertical stabilizer, which tops out at 14 feet.

But it’s the wings that catch your eye. There are two, one behind the other, mounted high on the fuselage and connected by elongated pods. Each pod holds a 750-horsepower Pratt & Whitney Canada turboprop engine positioned ahead of the forward wing, a retractable landing gear strut in the space between wings, and a fuel tank. The tandem wings also are “wet,” but rather than fuel, they’re filled with water for ballast. To explain: In the full-scale version the wings would carry aviation fuel, but for simplicity’s sake the fuel-line plumbing in the subscale model’s wings were omitted. Hence the subscale plane holds fuel only in its nacelle tanks. This power plant and fuel tank package gives Rutan’s test ship a top speed of about 345 mph and a range of slightly more than 1,000 miles.

The 38-foot-long front wing, which angles upward a bit more than the

rear, doubles as a canard. The rear wing, with a 47½-foot span, extends about five feet farther out on either side. Both gliderlike wings have slender high-aspect-ratio shapes that provide good long-range flying efficiency. When the AT³ banked and turned during its demonstration flight, the wings looked like two Popsicle sticks glued across a paper tube.

But the high-aspect-ratio airfoils raise a problem: “Slender wings aren’t very strong when twisted,” Rutan said, “so to support the loads from fuel, engines, and landing gear we have two wings connected by the pods.”

Rutan’s approach is radical. “To make a long, skinny wing work, you need a lot of lift, but not much weight,” Dougherty said. “So what Burt did was to put the engines, landing gear, and fuel out there to distribute weight along the wing.”

“But when you do that, the wing has to be stiff enough to withstand the loads,” Dougherty explained. “So his

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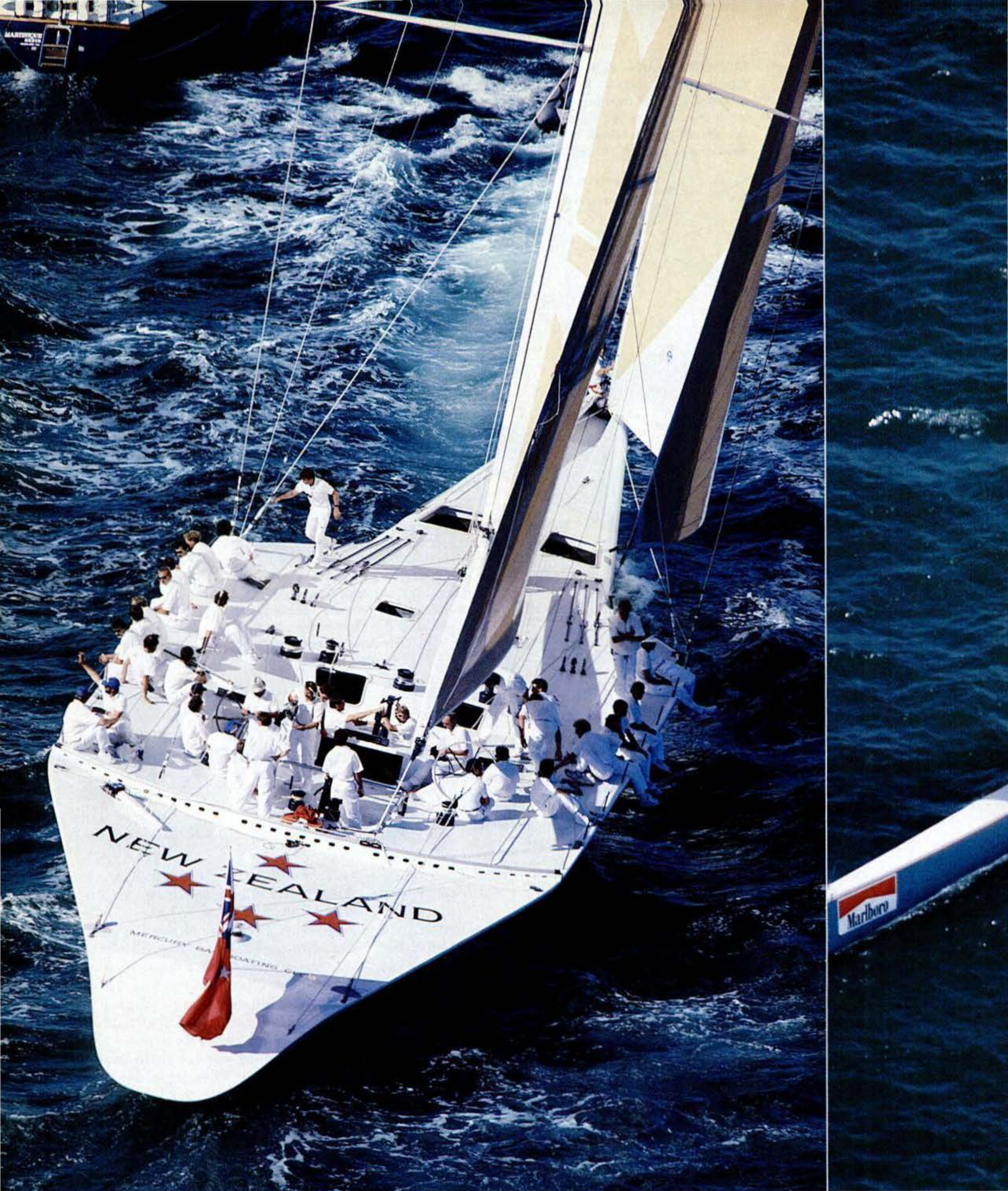


PHOTO BY DAN NERNEY/DOT

THE ODD



PHOTO BY BOB GREISER

COUPLE

New Zealand's surprise challenge for the America's Cup set the scene for a yacht-design free-for-all. The Kiwis' monster boat is so light a crew of 40 is used for ballast. The U.S. response: a super-fast catamaran with a wing sail that looks as if it were pinched from a Boeing 757.

By NAOMI J. FREUNDLICH

The harbor seas were calm and a gentle breeze sent the *Stars and Stripes* catamaran gliding from its resting place in San Diego harbor and out to the windier mouth of the north bay. As it came into sight, a flotilla of powerboats carrying journalists, photographers, and TV crews descended on the 60-foot cat, and news helicopters dove and buzzed overhead like mosquitoes—all to get a glimpse of the revolutionary America's Cup boat.

With the wind at eight knots, two crew members scrambled across the netted trampoline like spiders in a web and lay low on the sleek windward hull. Skipper Dennis Conner veered off the wind, sail tenders hastily adjusted the camber, or curve, of the wing's flaps and suddenly, lift off! The leeward hull and the four crew members it carried rose out of the water, seeming to defy gravity. The other hull hunkered down a bit in the water, and *Stars and Stripes* glided across the bay like an iceboat crossing a frozen lake. As the spectator boats gunned their engines to chase the fleeing multi-hull, the captain of the boat I was on reported a speed of 18 knots, about 21 mph. Shaking his head with disbelief, one New Zealander muttered, "That boat's going to blow us out of the water."

The speedy catamaran is Sail America's answer to a maverick America's Cup challenge waged by New Zealander Michael Fay just five months after the United States reclaimed the Cup in Australia (see sidebar). Breaking

Continued

The battle of the wings: The next America's Cup challenge could pit a 123-ft. monster boat with a winged hull (far left) against a 60-ft. catamaran with a wing sail. With enough wind to "fly a hull," the odds are the cat will outperform the monster.



PHOTO BY DAN NERNEY/DOIT

CHALLENGER

Looking a bit like an aircraft carrier with sails, the Kiwi boat carries a crew of 40 to 50, about 20 of whom will sit out on the wings and act as ballast (left). The hull is constructed over a wooden form using high-tensile carbon-fiber fabric laminated over a honeycomb Nomex nylon core. The wings require additional alloy support frames to handle the stress of the rigging that will be anchored on the deck. After the hull has been vacuum-cured, the "filling and fairing" process begins. In the photo below, a pink-colored surfacing compound made up of tiny "micro-balloons" is spread out over the hull to fill any small hollows. Workers then sand it back to create the ultra-smooth surface necessary for minimum drag. Parts of the deck weight less than 1 lb. per sq. ft. —lighter than $\frac{1}{16}$ -in.-thick aluminum.

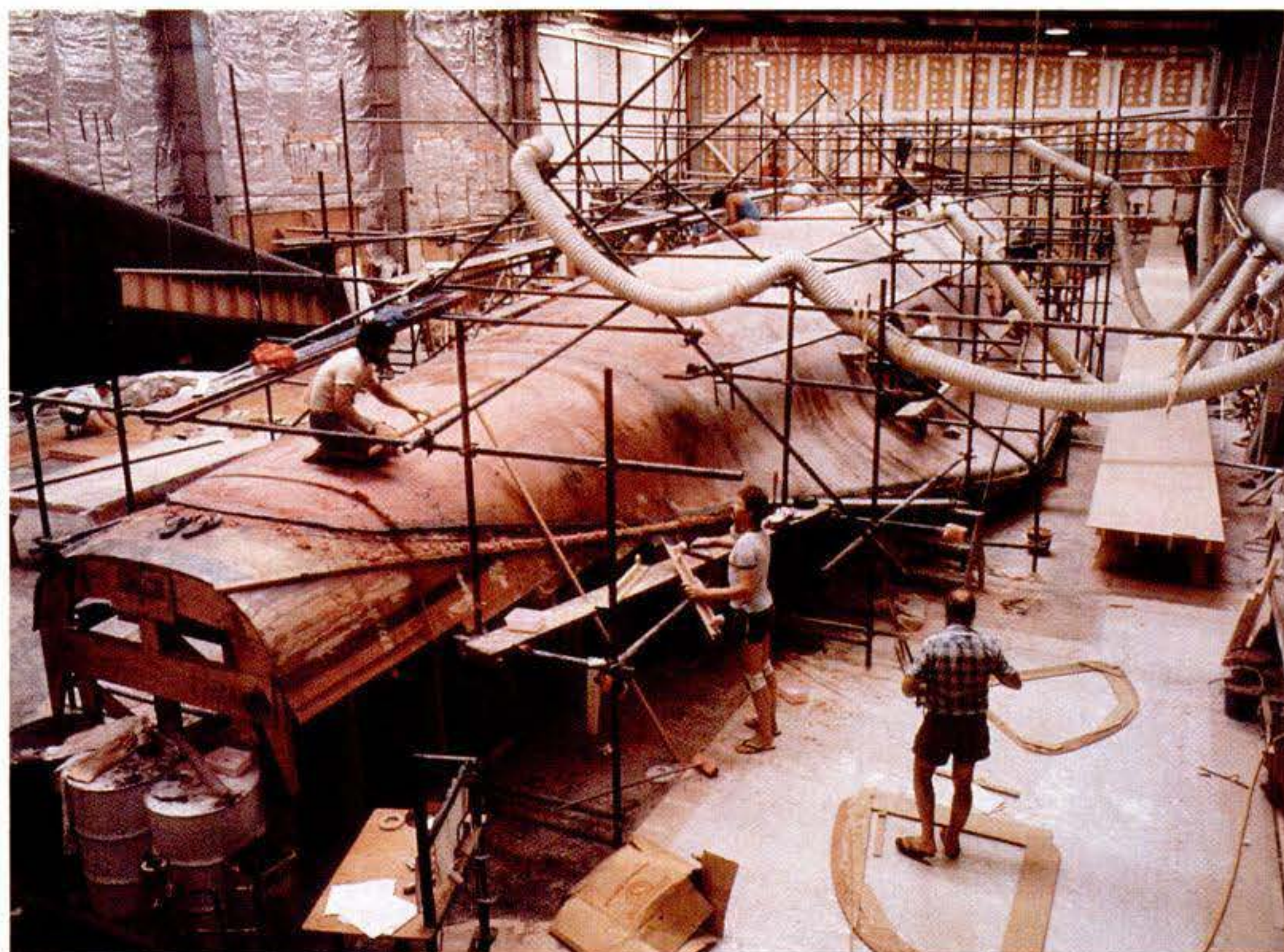


PHOTO BY ROB TUCKER

out of a 30-year tradition of racing 12-meter yachts whose dimensions and materials must conform to a formula, the only design limit in this most recent challenge is the waterline length of the hull.

The challenger: a 90-foot-at-the-waterline ultra-light mono-hull with an enormous sail area and an unusual winged hull. The U.S. defender: a 60-foot catamaran, also ultra-light, that sails on knife-edge hulls and sports a high-tech wing sail. Both boats attain speeds more than twice that of the wind and are made from the most advanced carbon-fiber composite materials. Neither has ever been raced before. Although there is bitter fighting between the racing camps as to the legality of racing a multi-hull against a mono-hull, the overall view is that the America's Cup will never

be the same. Tom Ehman, vice president of Sail America, the syndicate chosen to defend the Cup, says, "It's become a design free-for-all."

Monster boat

If Michael Fay had intended to add drama and excitement to the America's Cup, he couldn't have picked a better boat. The *New Zealand's* dimensions harken back to the huge J-boats that challenged for the America's Cup in the early 1930s: 123 feet long with a mast that stretches up 160 feet, or about 16 stories. Including a spinnaker, the sail area is over two-fifths of an acre; it takes 25 people to move the mainsail; and the thin bulbed keel has a 21-foot draught. The deck of the mega-yacht, nicknamed *Big Boat* by the New Zealanders, is 26 feet wide. The boat is so large that a special

crane had to be brought to San Diego from Texas to fix the mast into position and to lift the boat out of the water each night.

Bruce Farr, chief designer of the *New Zealand*, is no stranger to controversy. His Annapolis, Md., design firm was responsible for the much-disputed fiberglass keel on New Zealand's 12-meter *Kiwi Magic* that made it to the challenger finals in Fremantle, Australia, in 1987. Farr, along with materials specialist Russell Bowler, has designed many racing boats, but the *New Zealand* is truly a first. It takes some of its design characteristics from 35-foot ultra-light crew-ballasted Lake Garda boats, named for the lake in Italy where the boats are raced. *New Zealand*, twice the size of a 12-meter, but about the same weight, is also partially crew ballasted.

The winged hull is one key to the Kiwi boat's speed. "We wanted the boat to have as little resistance [wave drag] as possible by keeping wetted surface at a minimum," says Talbot Wilson, a spokesman for Bruce Farr Associates. That meant a narrow hull at the waterline. But a narrow deck was impossible. One reason: The rigging to support the huge mast, with its 14-foot spreaders, must be anchored on the deck. According to Peter Wilson, shore manager for the New Zealand Challenge racing syndicate, the carbon-fiber mast needs a lot of support. "If it's lying on the ground and you pick it up in the middle, it will deflect about two meters before the ends lift off the ground." A wide hull is also needed to hold the 20-man "rail crew" that makes up 10 percent of the ballast. The optimum solution would

DEFENDER

The carbon-composite wing sail was constructed in an airplane hangar in Mojave, Calif., using standard aircraft-construction techniques. The leading edge (top), or fixed portion of the wing, had Mylar plastic film stretched across its ribs before it was fixed to the catamaran. The second version of the wing (middle) is 100 ft. high and made up of three elements (inset): 1) a fixed leading edge, or mast; 2) a pivoting flap; and 3) semi-rigid panels. The No. 2 element pivots in both directions to accommodate both windward and leeward tacks. The retracted flap lets air flow up from the underside of the wing to re-energize air flowing back along the foil. Although the wing sail cannot be reefed (a soft sail's area can be decreased in strong winds), the top semi-rigid panel can be removed onshore if heavy wind conditions are known beforehand. Reducing the camber of the No. 3 element reduces lift and de-powers the wing.

have been to suspend the human ballast out over the side using trapezes, but this is prohibited under America's Cup rules. The answer was to use the winged hull that tapers down to a 14-foot width at the waterline.

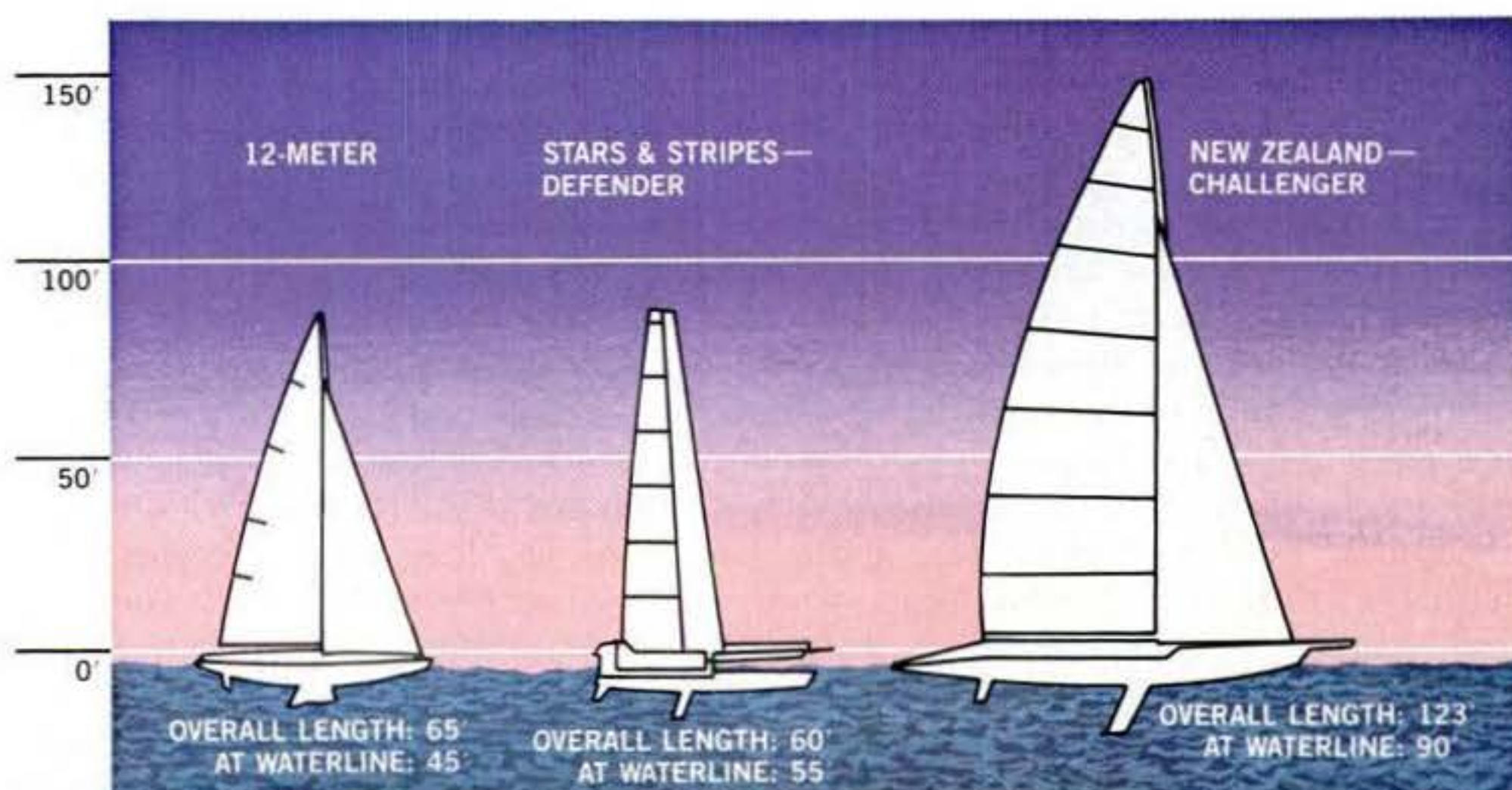
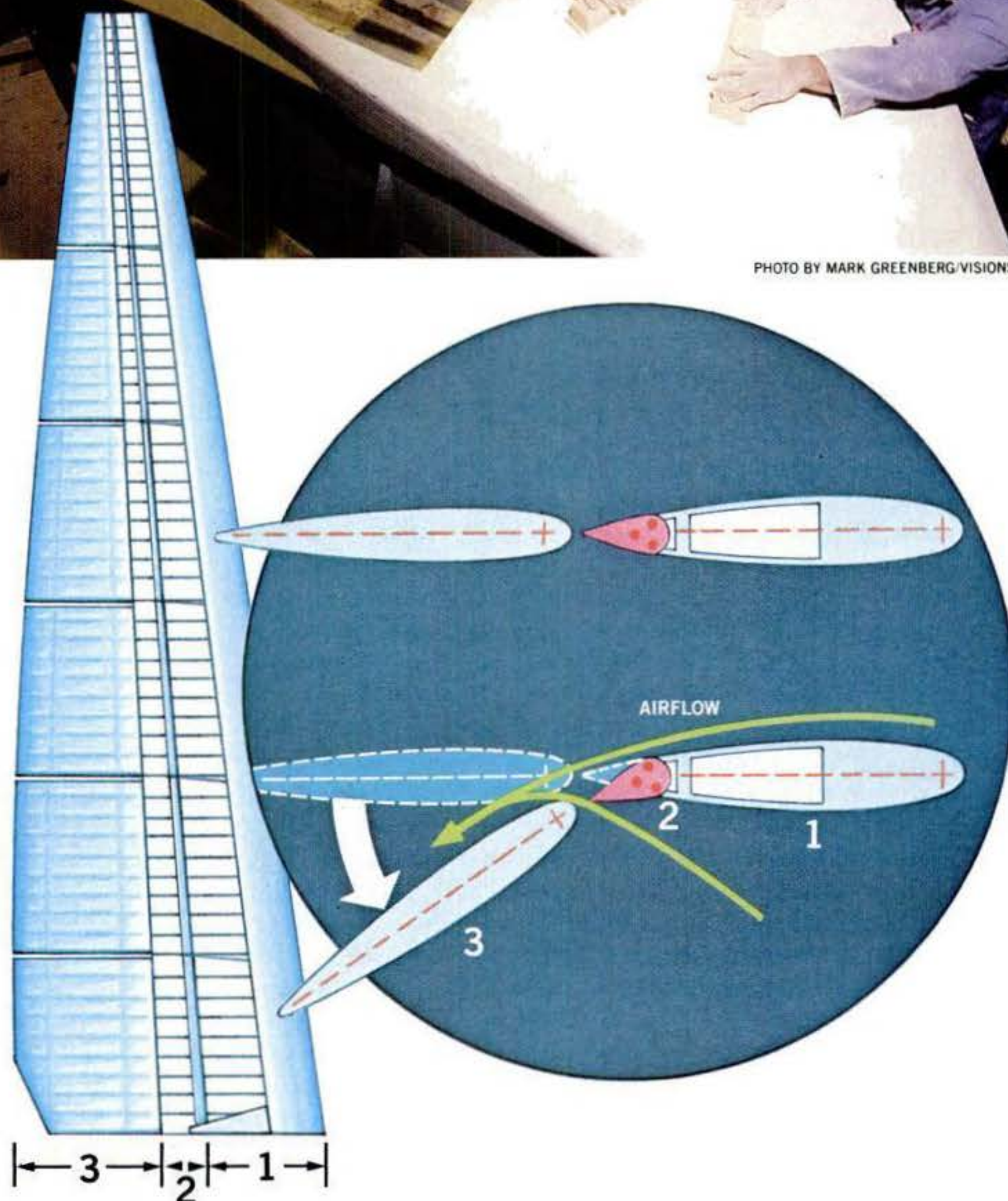
Aircraft-construction techniques are responsible for the lightness of this hull, as well as the American catamaran's hulls and portions of its wing sail. For the Kiwi boat, building a wood form in the shape of the hull is the first step. Then layers of carbon fiber, woven into a fabric and wetted with resin, are laid over a Nomex nylon honeycomb core, a standard sandwich technique used in aircraft construction. The final layer is a filler coat—epoxy resin containing a lightweight filling powder—which is "faired," or sanded down, to make sure the hull is ultra-smooth. The hull is cured by enclosing it in a big plastic vacuum bag. Bowler calls it "clamping" the laminates to the core. The clamping is achieved by atmospheric pressure outside and a vacuum inside.

While work on the hull progressed, the Kiwi electronics crew was also busy designing an extensive system using computer equipment and software supplied by Hewlett-Packard. *New Zealand* has three on-board computing systems, including a rig analysis system that takes data from 48 strain gauges; a performance measuring system that uses a velocity prediction program, or VPP, to dictate boat course; and a high-tech sail vision system that relies on video cameras taking shots of the sails every one-third of a second. Information about the shape of the jib and mainsail

[Continued on page 114]



PHOTO BY MARK GREENBERG/VISIONS



New Zealand is thought to weigh about the same as a 12-meter (60,000 to 100,000

lbs.). The cat, about equal in length to a 12-meter, weighs a scant 7,000 lbs.

DIAMOND POWER

Scientists are now laying down ultra-thin layers of genuine diamond on a host of solids. The result could be a new generation of long-life cutting tools, scratch-resistant lenses, crash-proof computer disks, and semiconductor chips that can survive the rigors of outer space. First product: a digital audio speaker with a diamond-clad tweeter.

By GORDON GRAFF

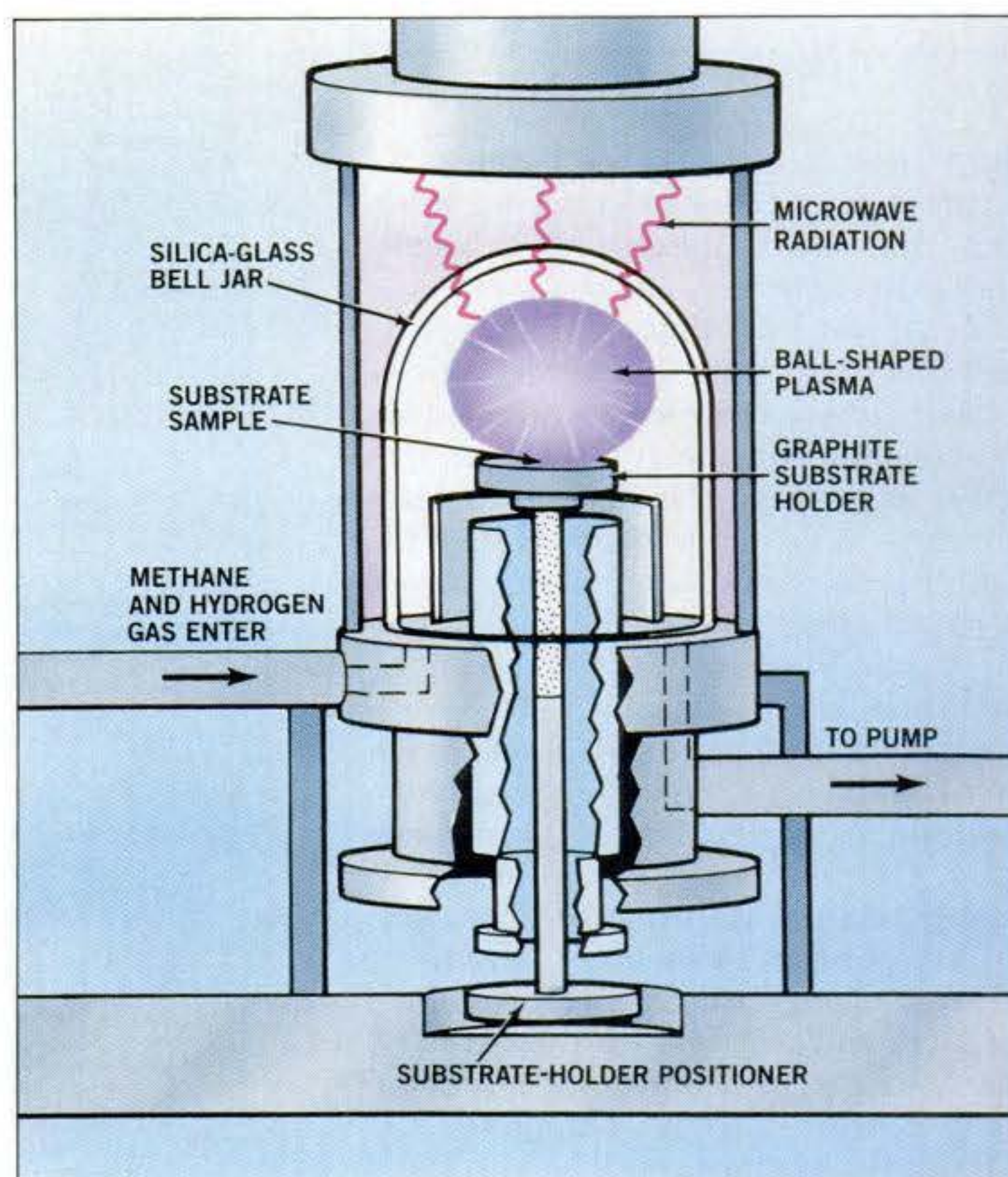
UNIVERSITY PARK, PA.

A luminescent purple ball floats inside a glass bell jar, casting eerie shadows on the walls of the darkened laboratory. "Now watch," says Russell Messier, an associate professor of engineering science here at Pennsylvania State University's Materials Research Laboratory. "We're about to make diamonds." On a nearby instrument console Peter Bachmann, a visiting scientist from the Philips Research Laboratories in Aachen, West Germany, flips a few switches and adjusts gas valves. The ball suddenly turns blue and contracts; then it slowly descends until it surrounds a flat, shiny inch-wide silicon wafer sitting in a graphite holder below. The wafer glows orange, then white.

"We're depositing a thin film of diamond right on that wafer," Messier explains. Throwing on the lights, Messier gives me a primer on Penn State's recipe for cooking up diamond coatings from methane, hydrogen, and argon. "It's really simple. We blend the gases and pump them at low pressures into this bell jar. From the top we bring in microwaves—the same type found in your microwave oven." The microwaves, he explains, both heat the wafer to 1,700 degrees F and generate the glowing ball of plasma—a swirling mixture of ionized and excited-state gases—which plates out a thin diamond layer (about a millionth of an inch thick) on the wafer in about five hours.

"Let me show you what the wafer looks like when it's finished," says Bachmann, holding up a dull gray disc that reflects rainbow colors. "I know it doesn't look as if it's coated with diamond," he adds, "but here, take a look." He thrusts a photograph into my hand. "This is a micrograph of this sample under an electron microscope." The print reveals a boundless array of multifaceted gemstones carpeting an ebony surface.

The diamond-coating work being pioneered here and at academic and industrial laboratories throughout the world is the vanguard of a new technology that promises a cornucopia of novel products. These applications include high-definition digital audio tweeters, wear-resistant cutting tools, abrasion-proof windows and lenses for instruments, high-speed semiconductor devices, heat sinks for electronics equipment, crash-proof computer disks, even devices to generate high-power ultraviolet laser beams for the Strategic Defense Initiative. In fact, according to some estimates, the market for diamond-coated products could reach

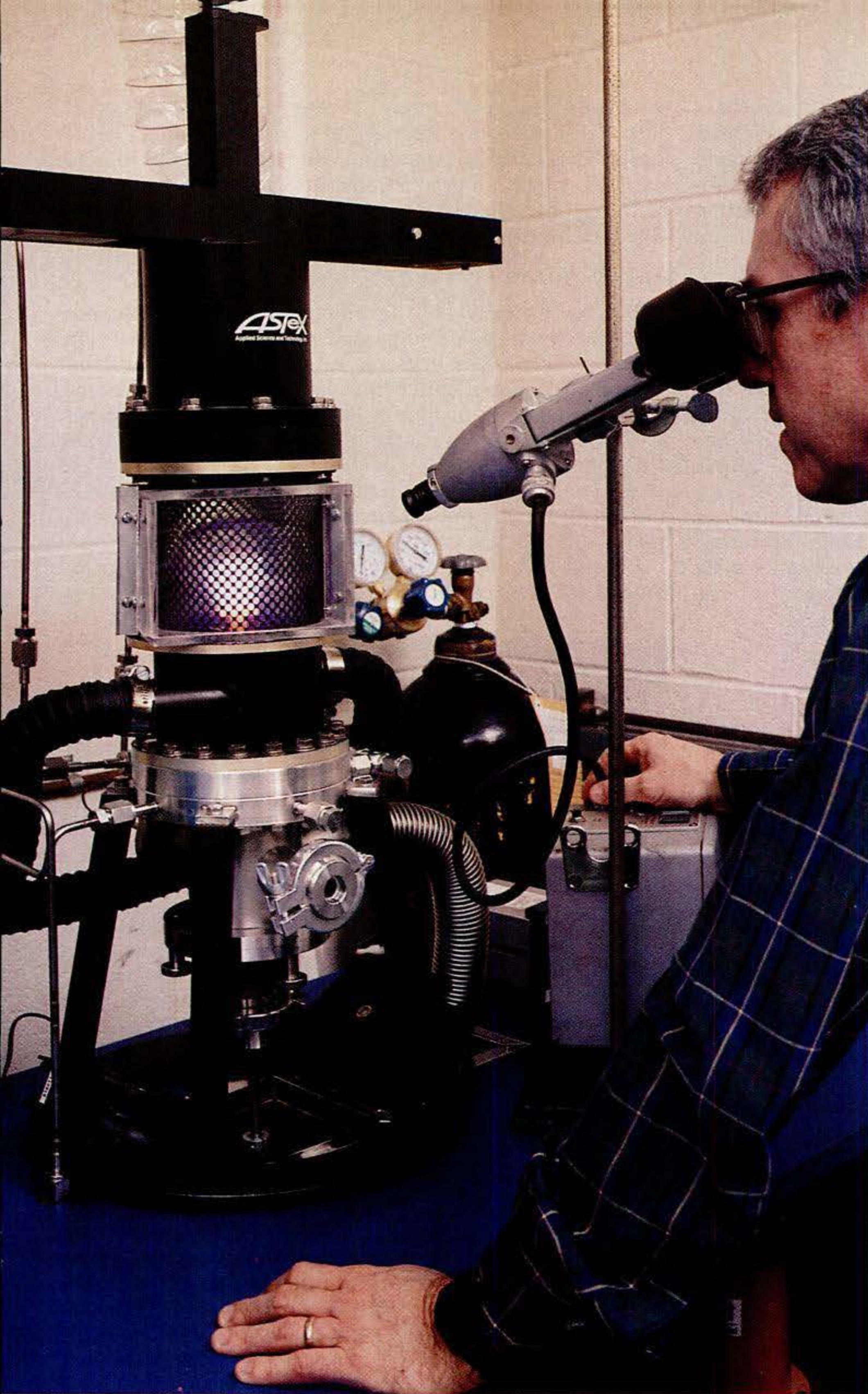


DRAWING BY ED LIPINSKI

\$400 million by 1993. Experts stress, however, that much research and development work lies between today's promise and tomorrow's payoff.

Diamond fever

Evidence of diamond fever is everywhere. For instance, a research consortium set up by Penn State two years ago to share its technology with industry (for a \$20,000 annual fee) now boasts 27 members, including such giants as IBM, Alcoa, Raytheon, Westinghouse, GTE, and Texas Instruments. At the same time, the U.S. government, through the Office of Naval Research (ONR), is sponsoring a range of diamond-coating projects at universities and research institutes under its \$4-million-a-year Diamond Technology Initiative program. Meanwhile, Japanese companies seem to have taken an early lead, having filed more than 500 patents in the field. Firms such as Sumitomo Electric Industries, Mitsubishi, Hitachi, Toshiba,



Microwave plasma-assisted chemical vapor deposition reactor (far left and left) is used by scientists at Penn State's Materials Research Laboratory to coat objects with diamond films. A mixture of methane and hydrogen is fed into a heat-resistant silica-glass bell jar where the object to be heated is raised to 1,700°F by microwave radiation. The microwave energy also causes the gas molecules to form a plasma of individual charged and excited-state hydrogen and carbon atoms. When the hot plasma comes in contact with the hot object to be coated carbon atoms deposit themselves onto the surface as a hard film of diamond crystals.

The substrates (above) are all coated with thin-film diamond. At the bottom is a circular silicon wafer with a 2.75-in.-dia. coating of diamond in the center. The even gray color of the deposition indicates that the diamond film is uniform in thickness. The smaller circular (on pedestal) and rectangular substrates are earlier, less-even diamond depositions on silicon. The rainbow-hued interference patterns indicate that the films vary in thickness. The small gray rectangle is a sialon ceramic cutting-tool insert. Machining tests on abrasive silicon-aluminum showed that the diamond coatings improved wear resistance.

PHOTOS BY GREG SHARKO

Showa Denko, Matsushita, and Seiko rank among the key Japanese players.

All proposed applications of diamond films take advantage of the unique properties of crystallized carbon. These attributes include unsurpassed hardness (diamond is the hardest substance known); unmatched ability to conduct heat and electricity; high transparency to light; and resistance to corrosion, radiation, and chemical attack. Until the early 1980s, however, these properties could not be harnessed because diamonds for commercial and industrial purposes were available only in tiny clumps made by a costly high-temperature, high-pressure process first developed in the 1950s by General Electric.

But recently, Soviet, Japanese, and, belatedly, American investigators have developed a wide variety of techniques that can be used for laying down thin coatings of diamonds on substrates such as silicon, metals, ceramics, and even natural diamond. The result is a global race to

be the first to commercialize diamond-coated products.

Despite the frenetic activity, only two diamond-coated products have yet hit the market: a high-frequency-response digital audio tweeter and an abrasion-resistant window for X-ray instruments. Still, the level of interest is high, say experts. "These are the letters we've gotten asking for information on our diamond-coating work," says Messier, pointing to a half-foot stack of papers on his file cabinet. The papers bear letterheads such as U.S. Army, NASA, and 3M.

Diamond discoveries

Today's diamond-coating mania had its start back in 1977. In that year Soviet investigators Boris Deryagin and Dmitri Fedoseev of the Institute of Physical Chemistry in Moscow published a landmark book. Until that time, attempts to deposit diamond coatings had failed. The prob-

Continued

lem: While the process deposited some diamond crystals, it also simultaneously deposited black, crumbly graphite, a much more stable form of carbon than diamond. Deryagin reported that he had added excess hydrogen to the methane in the reaction mixture and that this combination favors the formation of diamond over graphite.

Deryagin and Fedoseev, along with Boris Spitsyn, published their results in English in 1981, but U.S. researchers were skeptical. "There was sort of a mystique about diamond," recalls Karl E. Spear, a ceramic science and engineering professor with Penn State. "People didn't believe you could make diamond in low-pressure apparatus. It seemed like turning lead into gold."

The Japanese, however, had no such reservations. Scientists at the National Institute for Research in Inorganic Materials in Ibaraki, Japan, promptly duplicated and extended the Soviet work. "I first saw the diamond films on my trip to Japan in 1984," says Rustum Roy, a materials professor at Penn State, and the person responsible for awakening the United States to the development of diamond-coating technology abroad. "Just by coincidence, I was going on to Moscow. When I got there I dropped in on my friend Deryagin." Looking at the diamond crystals in Deryagin's lab, Roy was awed. "There they were—thousands of these sparkling little fellows."

Upon his return to the United States, Roy called officials at the ONR and spooked them with tales of the Soviet lead in this potentially strategic technology. He soon came away with a \$100,000 research grant to see if those results could be duplicated. He succeeded, and the ONR expanded its efforts the following year to fund investigations by other organizations. In 1986 Penn State set up its consortium.

Brilliant sound

It is true diamond that has captured the attention of most researchers and the imagination of the informed public. In fact, the allure of a diamond coating is a key selling point in the new tweeter, which is manufactured by Sumitomo Electric and sold in the United States by Sony. The tweeter, which is incorporated into Sony's \$1,000-per-pair APM-66ES speakers, consists of a sandwich of aluminum skins and damper materials enclosing a rigid honeycomblake aluminum material. The diamond layer, which is less than one-millionth of an inch thick, is produced by a chemical vapor deposition process that coats one of the outer surfaces of the aluminum structure.

Ikuo Chatani, a project engineer in Sony's Audio Components division in Tokyo, says the main function of the diamond layer is "to add rigidity [to the speaker cone]

without adding much mass." The net result, Chatani notes, is a flat frequency-response curve out to about 40 kilohertz, "less harmonic distortion, and a good signal-to-noise ratio." Citing high production costs, Sony spokesmen note however, that the company currently has no plans to use diamond coatings in other products.

Adamantine surfaces

Besides the tweeters, the only other diamond-film products that have been commercialized are coatings for windows of X-ray detectors for analyzing ores and other samples. This application was developed by Crystallume, a small company in Menlo Park, Calif. "In many cases, it's important to have a wear-resistant coating on something that measures or touches an object, or that is exposed to abrasion," says Thomas A. Schultz, Crystallume's president. "If you put diamond on these surfaces, we estimate that they'll last up to ten times longer."

Beyond their value in X-ray detectors, says Schultz, diamond coatings can also prolong the lifetimes of windows

in infrared-sensing instruments used in jet planes, missiles, or industrial analytical instruments. "Even a raindrop can be abrasive hitting an aircraft window at six hundred miles per hour," he says. The infrared-sensor coatings are in prototype form, he notes.

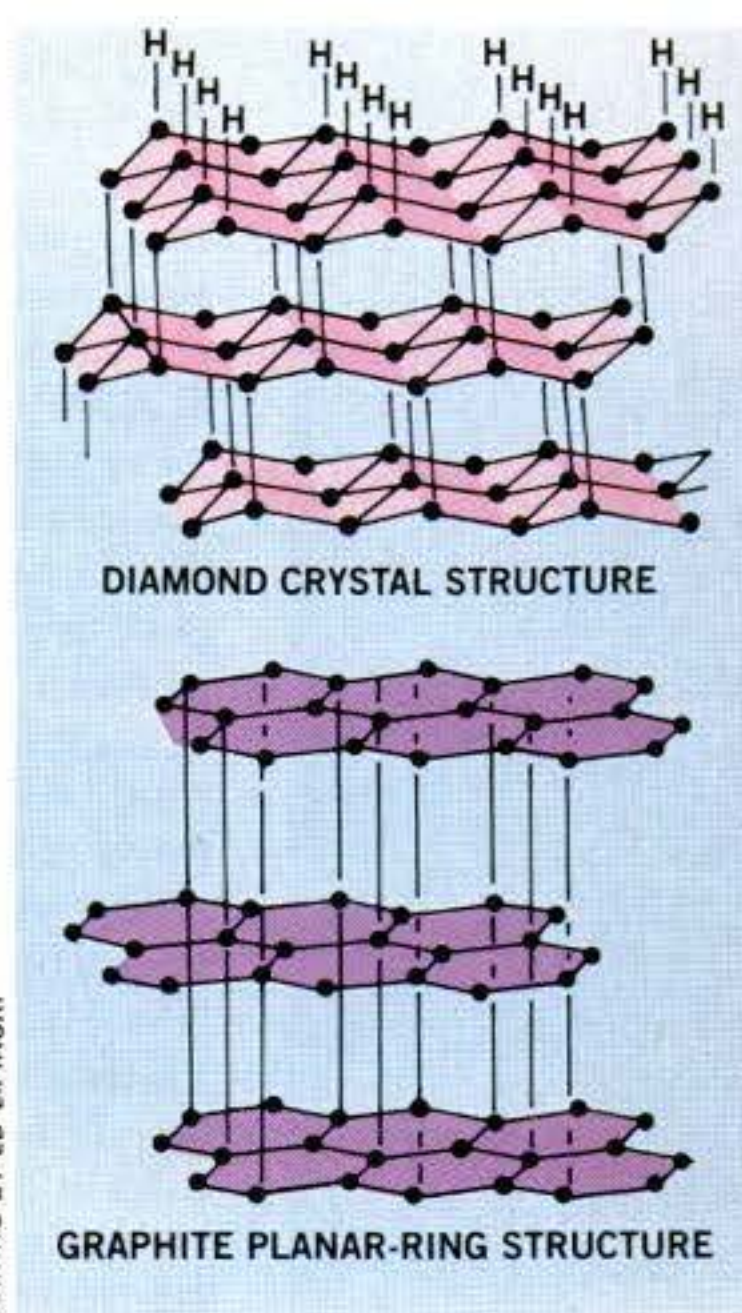
Diamond bits

If the diamond films are useful in preventing scratches and pits on lenses and windows, they're even more so when it comes to protecting drill bits, cutting tools, and other objects that take a constant beating. In a sunny office here at Penn State's Materials Research Lab, Bill Drawl, a ceramics engineer, shows me some samples of sialon (silicon-aluminum-oxygen-nitrogen) ceramic cutting-tool inserts he's just coated with diamond. Like the wafer Bachmann showed me, they hardly look like anything you'd see in a jewelry store window. "The diamonds don't show up in regular office light," says Drawl. With a pair of tweezers he carefully holds a half-inch square gray sialon disc up to the sunlight. "Now do you see

them?" Indeed, the surface takes on the unmistakable spectral glitter of diamonds.

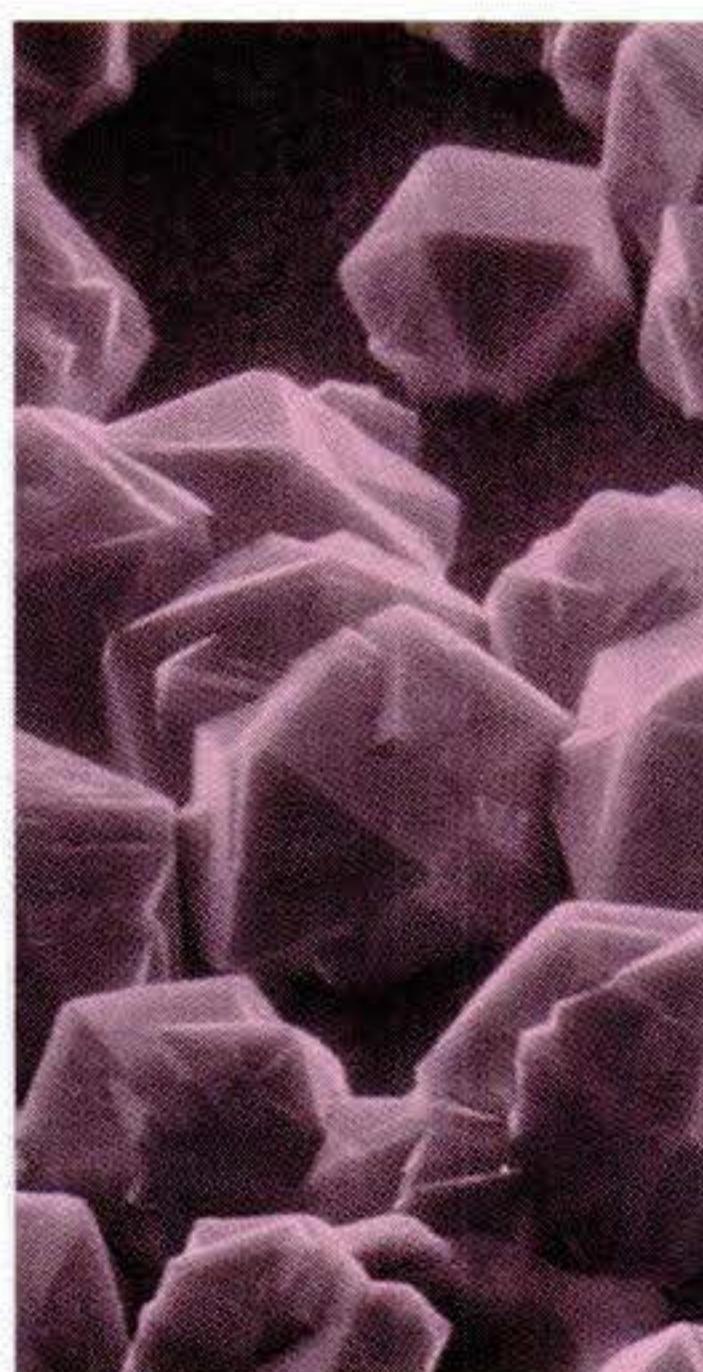
"We cut high-silicon-containing aluminum with similar sialon inserts," says Drawl as he puts down the piece. "That's an abrasive material that's hard to cut. The tests showed a big improvement in wear resistance: The coated cutting-tool inserts exhibited no visible wear, while the uncoated inserts didn't stand up nearly as well."

All of the samples with which Drawl has worked are flat. But coating three-dimensional shapes—like complex



DRAWING BY ED LIPINSKI

Scientists studying the deposition of diamond films from hot plasmas (ionized gases) believe that hydrogen atoms play a vital role in stabilizing diamond as it forms. Initially, carbon atoms in the plasma plate out as layers consisting of typical diamond crystals—a network of six-membered "puckered" rings of carbon (top left). Hydrogen atoms, also present in the plasma, are thought to form bonds with the uppermost layers of the carbon atoms in the diamond lattice. These carbon-hydrogen bonds are believed to hold the puckered diamond-crystal structure in place until the next layer of carbon atoms deposits out, taking the place of the hydrogen atoms. Without the hydrogen bonds, the puckered diamond lattice would quickly revert to the flat six-membered planar ring structure typical of graphite (above left). The scanning electron micrograph (right) shows an initial layer of diamond crystals on a dark silicon nitride ceramic.



[Continued on page 90]



Popular Science **SUNSPACE!**

From modest bump-outs to opulent additions, they're today's hottest home improvement—bringing the outdoors in and making any home brighter and bigger. Today's choice of kits is broad—but can you erect them yourself? What do they cost? Should the support frame be wood or metal? What type of glazing is best for your site? Which side of the house should they attach to—and which room? Will they be too cold in winter and too hot in summer? The articles in this special section will help you decide which sunspace is right for your home, whether you should tackle the job yourself, and how to choose from the dozens of glazing options and accessories now available.—*The editors*

Double your

This homeowner liked the idea of a sunspace so much he didn't settle for just one. He built a kit into each side of a spliced-on extension, transforming the back of his home.

By AL LEES

When a homeowner in Brewster, N.Y., decided to expand a little breakfast-nook projection from his south-facing rear wall, he knew he wanted to incorporate a kit sunspace into a side wall. But he couldn't decide which side, so he ended up ordering a kit for both. Because these units had to be custom-made to fit the framing of the new wing, he contacted Solar Additions, a sunspace company that's well-known for working with homeowners. (See source list at end of article.)

Solar Additions had just introduced a new "window room" it calls Nature's Window. Basically, it's a four-foot-deep, nine-foot-high extension with 46-by-76-inch window bays (three, four, five, or more) set vertically between laminated arches of either yellow pine or redwood.

The completed interior of a three-bay Nature's Window is shown on the cover of this special section. Exterior shots of both the three- and four-bay units added to the Brewster wing are on these pages.

To order a kit tailored to your needs you send a photo or sketch of your home's south-facing wall to Solar Additions. Its designers respond with design sketches and estimates. When you buy the custom-made unit it arrives in pieces with instructions for assembly. (Or the company will help you find a qualified local contractor.)

Often you'll have to cut out a section of the wall where Nature's Window will be spliced on; but in the case of the Brewster house, the kit frames were simply tied into the wall and roof framing for the new wing. The new roofing was extended down over the insulated roof deck of the sunspaces at both eaves. (Solar Additions recommends a venting skylight for each bay, but this feature is optional.) Once the new siding was applied, the kits all but disappeared when viewed from the exterior. They were absorbed into the

general structure of the extension.

But that aspect of this project is atypical. It's more common for kits of this type to be spliced onto a south-facing wall of a living room, bedroom, or kitchen. The erection procedure is basically the same—and basically as simple. I watched the complete four-bay unit in Brewster go up in one day with a crew of three.

The unit must sit on its own foundation, poured or concrete block. The floor can be an insulated slab or sub-

You run two continuous parallel beads of silicone sealant along the full width of the subfloor before setting the floor plate in place. The wall plate may have to be notched into the siding or shimmed out. Do a neat job because it remains visible after assembly.

Next, insert the preassembled knee-wall panels, sealing all joints and anchoring the frames to the arches. At our site the bottom frames of these panels hadn't been factory-notched to clear the bolt heads securing the arch

brackets, so a router came in handy. Insert header strips between the hips of the arches, then add the end walls. You can opt for these solid panels to be factory-assembled. We put ours together on site.

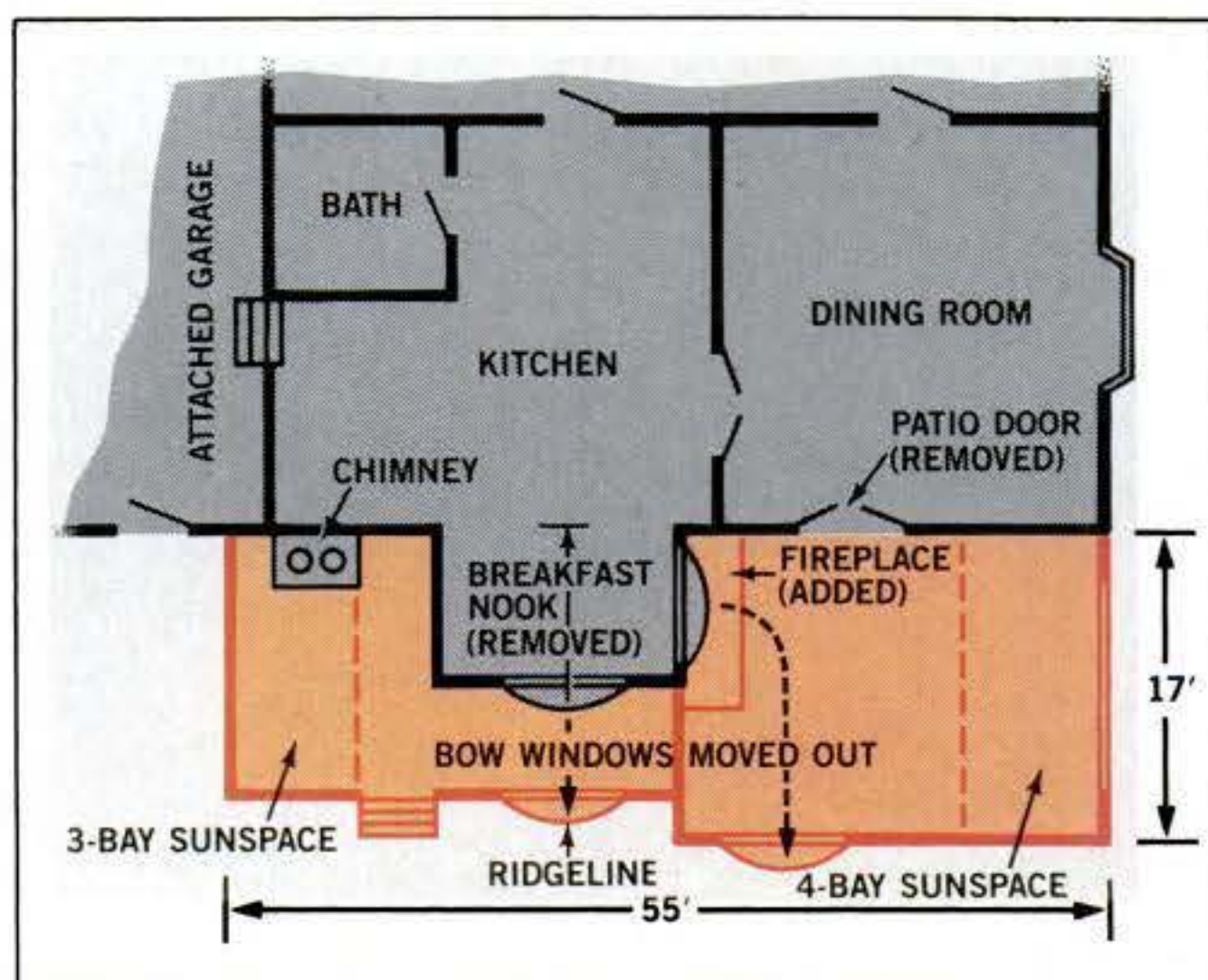
Now nail the tongue-and-groove 2×6s across the arches to form a roof deck. And if you've chosen the skylight option, cut a rough opening centered on each bay for which a skylight has been supplied. Staple four-mil polyethylene (a vapor barrier) over the roof deck, then cut out the holes for the skylights and install the preassembled H frames, centering them around the skylight holes.

Cover the whole deck with rigid insulation, notching it to fit snugly around the projections from the H frames. After dropping in the skylights, apply head and bottom flashing.

In our project the tongue-and-groove roof deck butted against the ends of the 2×6 rafters of the main structure. When we nailed on the half-inch plywood sheathing (as a base for shingling) it came flush with the sheathing on the main roof. We drove five-inch ring nails down through the rigid insulation and into the 2×6 decking.

To install the glass, run an unbroken bead of the silicone caulk around the redwood casing and set in the double-glazed panel. Hold it temporarily in place with the blocking provided. Fill all voids between the panel edges and casing with silicone. Next day, install the redwood trim supplied.

Text continued on page 66



flooring over wood joists. Either way, you'll probably want to face it with ceramic tile to provide a heat-absorbing masonry mass.

No flooring material comes with the kit, which does include the laminated arches, the ledger and floor plates the arches span, glass, the roofing system, all required fasteners, hardware, and redwood trim. Options include the operable skylights and sun screens.

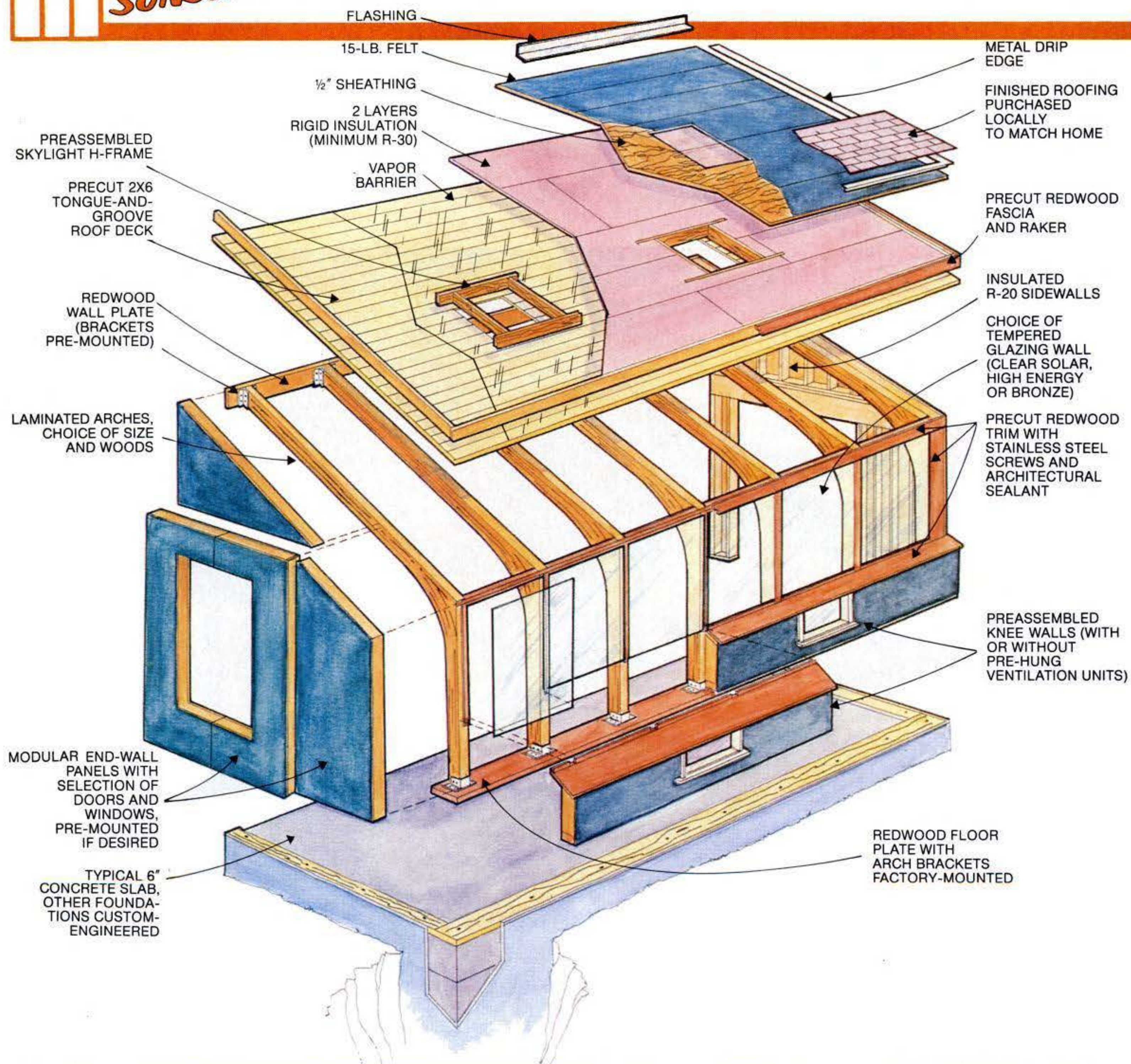
As the assembly photos indicate, erection isn't especially tricky because, as with most other factory-made kits, parts are designed to fit together. The critical starting point is checking that the redwood floor plate and wall plate are precisely parallel, because each comes with brackets already mounted at the proper spacing to take the laminated arches that bridge these brackets to support the glazing. If the plates diverge from parallel, some arches will be too long or too short.

pleasure

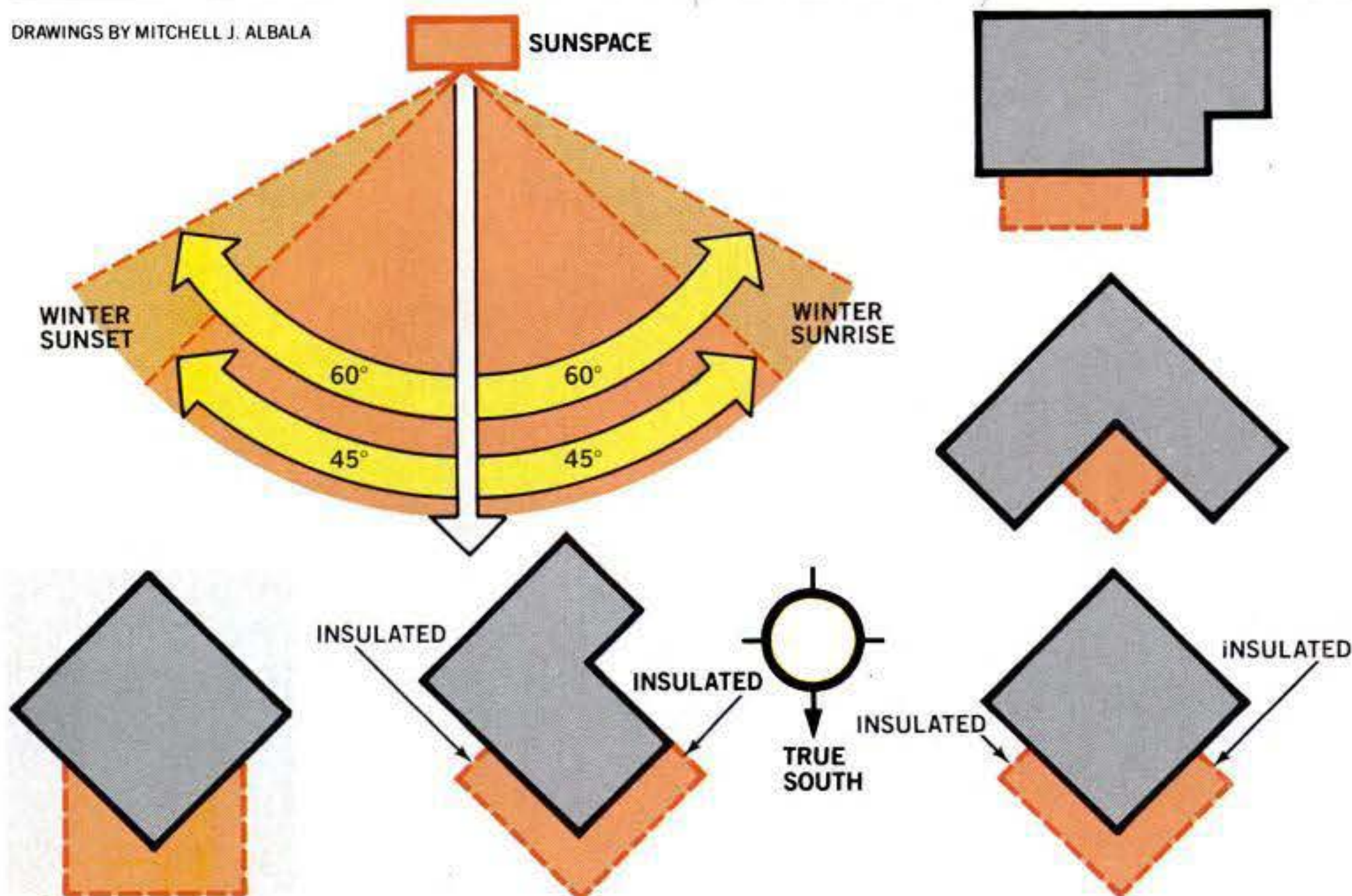


Top photo is an exterior view of the three-bay sunspace seen on a previous page, and shows how the unit is built into the house addition—an option made possible because the unit's manufacturer customizes each order. The upper skylights were added by the owner—lower three came with kit. BEFORE photo, above, shows the original projection from the back wall of this two-story tract house—a cramped breakfast nook with two bow windows that received little direct sun. As shown in floor plan (facing page) and AFTER photo (right), the owner expanded the projection from the existing ridge line and incorporated a sunspace at both eaves.





DRAWINGS BY MITCHELL J. ALBALA



How to site a sunspace

The survey map of your lot will show true north and south, but might not show how your house is oriented. If you site with a compass, you may have to apply a correction of as much as 23 degrees. (Compass and true south agree only on a line through Michigan and Florida.) Once you've found true south you can determine the area that should be free of obstructions. Use compass or protractor to locate 60 degrees east and west of true south as seen from your intended site. These are the points where the sun rises and sets in midwinter. Most solar heat is gained between the time from about 45 degrees east of south (9 a.m. solar time) to 45 degrees west (3 p.m.), so obstructions outside this zone are no problem. Floor-plan sketches show best ways to position a sunspace.—*John H. Mauldin*

Mauldin is a designer-builder of solar structures and the author of *Sunspaces—Home Additions for Year-Round Natural Living* (\$14.60 paperback; Tab Books, Blue Ridge Summit, Pa. 17294-0859), from which sketches at right have been adapted.

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The order in which you tackle these steps may vary. You'll note in the photos that we installed the vertical glazing before dropping in the skylights. This gave us more flexibility in handling the big, heavy panels of glass (a three-person job) because we could pop up—or down—through the open roof holes. Roofing the entire structure with fiberglass shingles over 15-pound roofing felt was the final job.

What's the difference between these add-on sunspaces and the old shed greenhouse? "Energy management," says Lee Stanley, pioneer sunspace designer and director of Solar Additions. "These units—installed for less than a new car would cost—are designed to tap solar energy for human comfort. And though you can certainly grow flowers and food in them all winter, they're meant as added living space. So they must be engineered for efficiencies well beyond those required by a greenhouse. Our models feature double glazing plus insulated roof and side walls to allow storage of solar heat in winter. They're ventilated to prevent overheating in summer. It's this kind of comfort that explains why

over 150,000 sunspaces have been added to U.S. homes in the past decade, and why this is one of the best ways to upgrade a house for resale."

You can't just tack a sunspace onto any wall, however. These units should be oriented within 30 degrees of true south (see sidebar). So how does this project manage a sunspace on both ends of the south-facing extension? By compromising proper siting.

A sunspace that doesn't face south can be a net loss as far as heat is concerned. If it's not in direct winter sun, not only will it fail to contribute any solar gain, it can be a big heat loser—unless you equip it with elaborate insulating drapes or shutters (see "Outfit Your Sunspace" in this special section). And that could cancel out the main reason for installing a sunspace: to open up your home to outdoor views.

I asked John Mauldin (author of the sidebar) which compromise was best when a *corner* of a house points true south, and it's impractical to wrap a sunspace around it. Do you add the unit to the wall angled east or west?

Mauldin told me his advice would depend on local weather patterns and

family lifestyle. "Are winter mornings overcast or foggy while afternoons tend to be clear?" he asked. "Then your orientation should favor the west. Do you like an early-morning warmup and perhaps a cozy breakfast in the sunspace? Or will you use it for unwinding, maybe with a spa soak?"

The Brewster homeowner has a choice. The "morning" sunspace gets direct sun earlier and longer, so its position off the kitchen makes it a good breakfast nook. The "evening" sunspace gets less sun, later, so it sports only three bays and is comfortable for cocktails.

But if you must settle for only one, you'll be happiest with a sunspace you've tailored to your site, lifestyle, and local weather. **PS**

MATERIALS FROM THESE SOURCES APPEAR IN THE PHOTOGRAPH THAT OPENS THIS SECTION:

Solar Additions, Box 241, Greenwich NY 12834 (Nature's Window sunspace); **American Olean Tile Co.**, 1000 Cannon Ave., Lansdale PA 19446 (8" hex Primitive Encore ceramic floor tile: 811 Almond); **Ernest Treganowan, Inc.**, 306 E. 61st St., New York NY 10021 (Tredmaid area rug by New England Guild); **Sunset/Richards**, 6000 E. Slauson Ave., City of Commerce CA 90040 (floor and table lamps); **Barcalounger**, 6900 Six Forks Rd., Raleigh NC 27609 (Hot Lines wicker furniture in honey pecan finish: modular seating and occasional tables); **Brewster Garden Center**, Rte. 22, RD 5, Brewster NY 10509 (flowers and plants)

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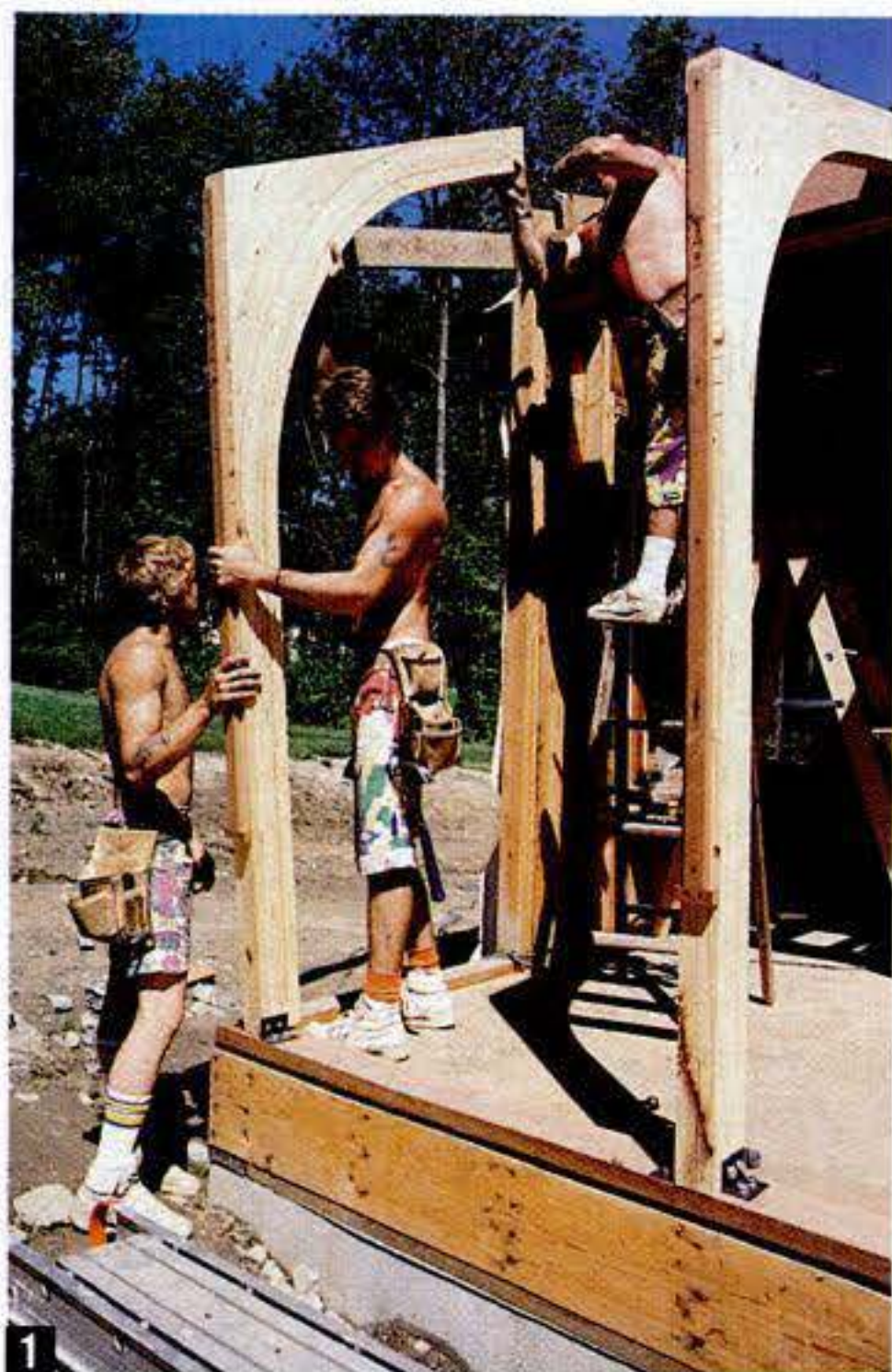
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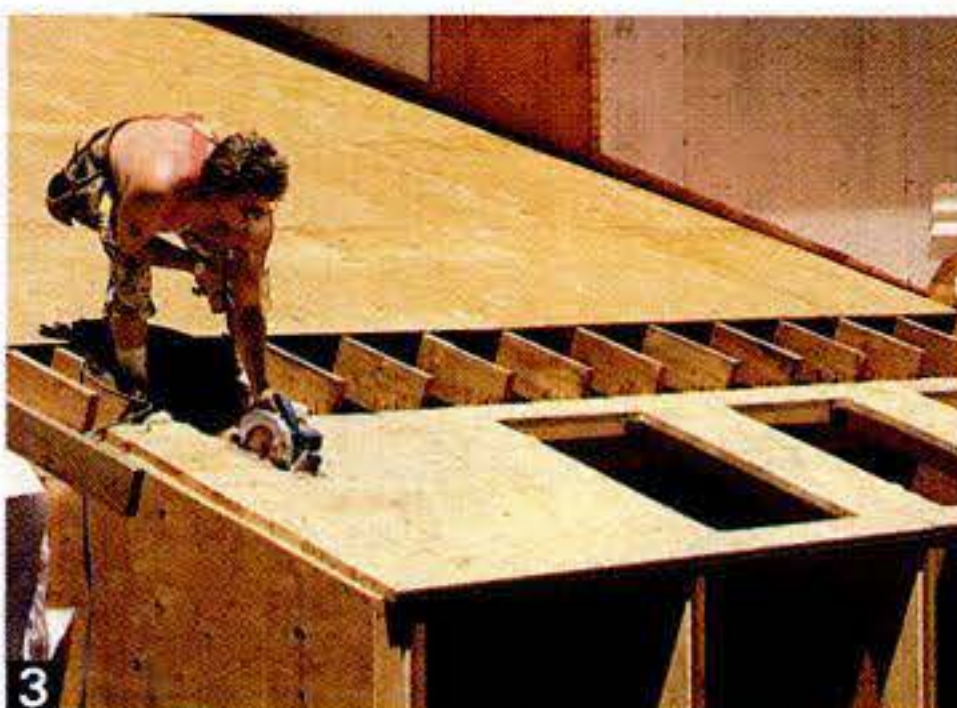
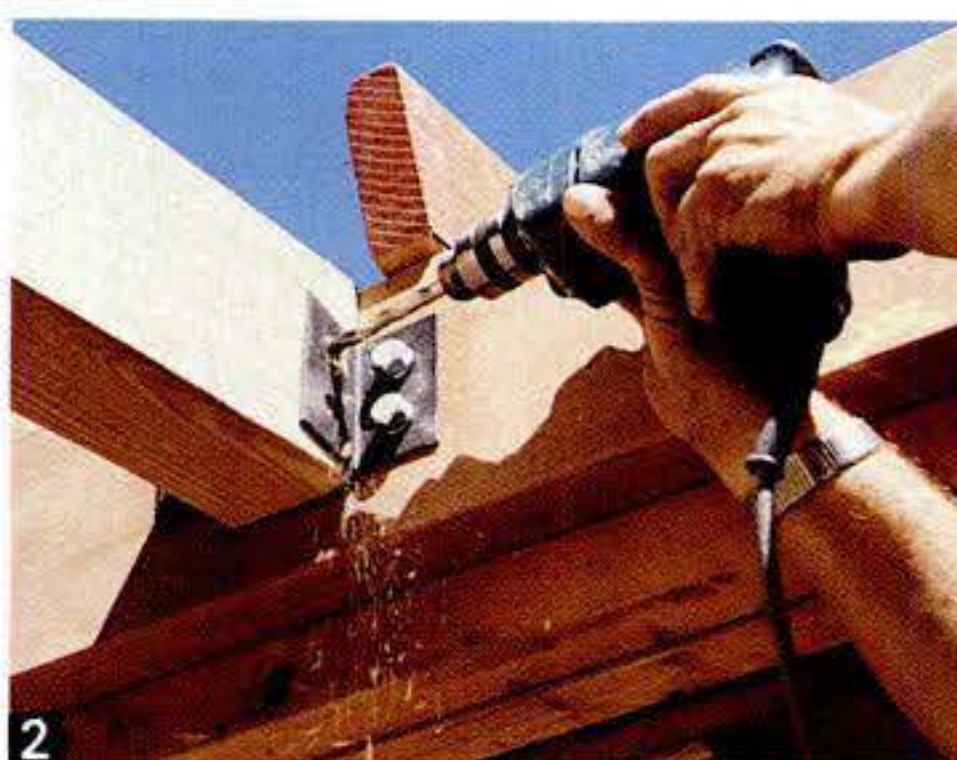
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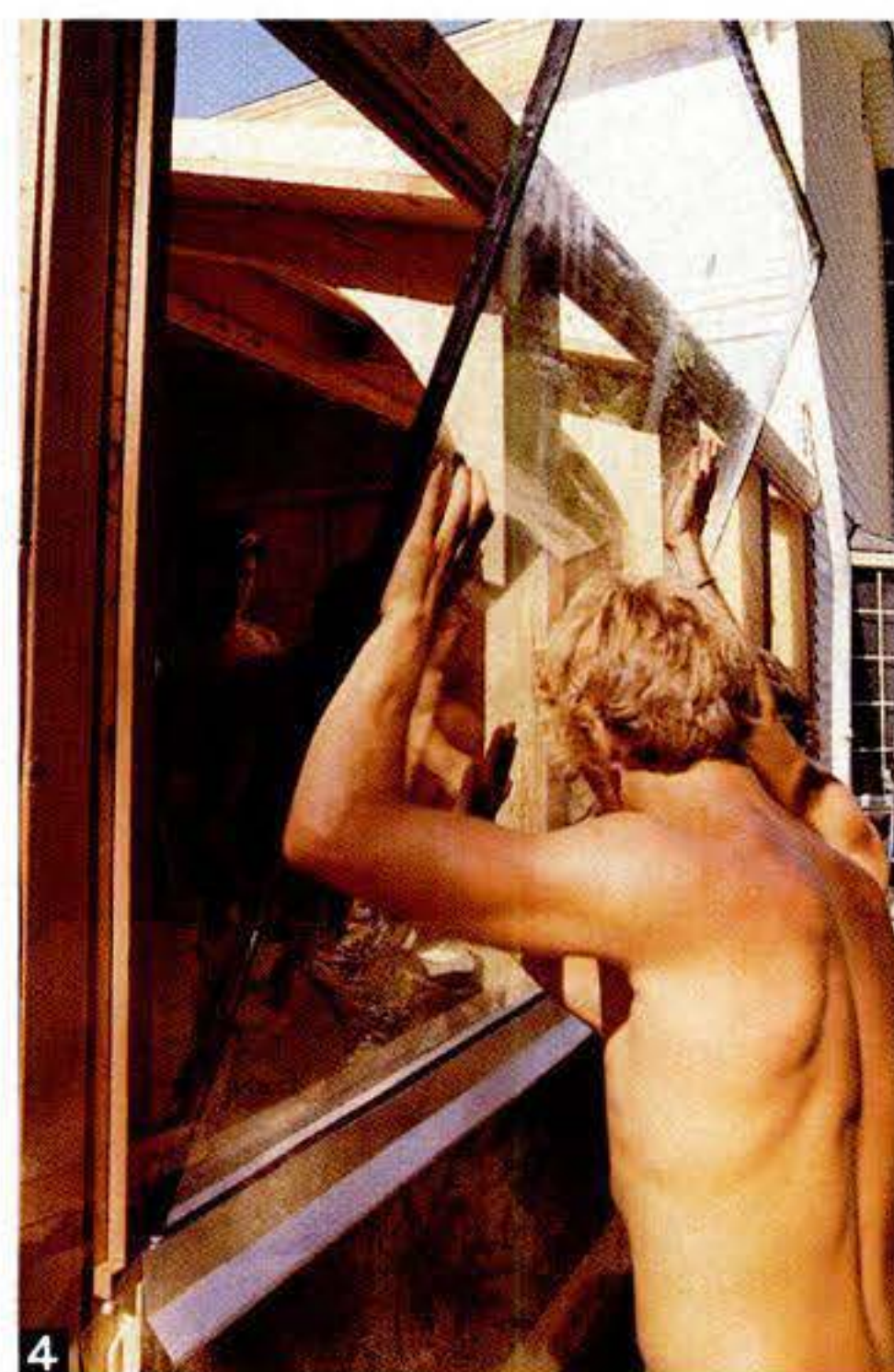
Four-bay sunspace goes up in a day



1 After floor plate with pre-mounted brackets is anchored to foundation's sill plate, laminated arches are tipped in place [1] and drilled through bracket holes at top [2] and bottom; then they're



3 bolted in place. Holes for skylights (one per bay) are cut through tongue-and-groove roof deck [3]. Note that deck is recessed below sheathing of adjacent structure to accommodate rigid insu-



4 lation. Final sheathing on unit—for nailing on shingles—will set flush with adjacent roof. Vertical glass is tipped into rabbets in frame [4]. Note sealed edge of the double glazing.



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Sun-sational sun rooms

Want to bring the outdoors in? You can start by building a glass room from a sunspace kit. There's a variety of styles and sizes available. Here's what you should consider.

By DAWN STOVER

Today's sunspaces come in almost any size—from a window bump-out to a two-story unit that spans the side of a house. They include greenhouses used to grow plants that can't survive outdoors, as well as sun rooms used for living space and solar heat collection.

If you have the time and talent, you can add a sunspace to your home with one of a new generation of kits that include all the materials you'll need. Here's what you should consider if you're thinking about purchasing a sunspace kit.

First, do you have the skills you'll need? You can hire others to pour the foundation and do the electrical wiring, but you'll still need some carpentry experience. Most experts don't recommend erecting a sunspace without the help of a local dealer.

"Back in the old days, when sunspaces were strictly greenhouses, leaks weren't critical," says Dr. Harold Gray, executive director of the National Greenhouse Manufacturers Association. But modern sun rooms may contain fine furniture. "It takes a little expertise to make the sunspace leak-proof," Gray says.

Also, the old greenhouses used single glazing, says Gray. "The standard lights [panes] of glass were much easier to handle." Today the sunspace may be glazed with slabs of double glass (see "Get Smart About Glazing," this issue). Even the smallest panels, 10 feet square, weigh about 50 pounds.

Do you have time to build a sunspace? Professionals can build one in a few days, but it often takes them much longer. "Allow a sufficient amount of time and expense to get the project completed," says Larry Chavez, president of Sunlite Industries, a sunspace-kit maker. And don't forget that the foundation, wiring, accessories, and finishing are "extras" that may cost as much as the kit itself.

If you've decided to build your own sunspace, how do you choose from the many kits available? The two most important considerations are the engineering and the ease of assembly.

"Before you buy any system, be sure the manufacturer is willing and able to provide stamped engineering calculations [prepared by a registered professional engineer] verifying the integrity of the unit you propose to buy," advises William B. Gilmer, president of Regal Manufacturing, a maker of skylights and sun rooms. "The company may charge an extra \$150 to \$250 for the service, but it's cheap insurance," he says.

Continued



An insulated wood roof (facing page) keeps out heat in summer, while angled glass lets in the low winter sun. Habitat's Solar Room has one-piece laminated cedar rafters, so there's no need to measure the angle. Pre-glazed aluminum frames fit neatly between rafters. The kit sells for \$11,544; A finished room costs about twice that

amount. The aluminum-framed Sunspot (above) comes with an installation video. Two people can assemble the basic 8-by-11-ft. room in about 12 hrs., claims the manufacturer, ODL Inc. This model, which can be ordered by your local home center or lumberyard, has a straight eave. Aluminum frames are more common than wood ones.



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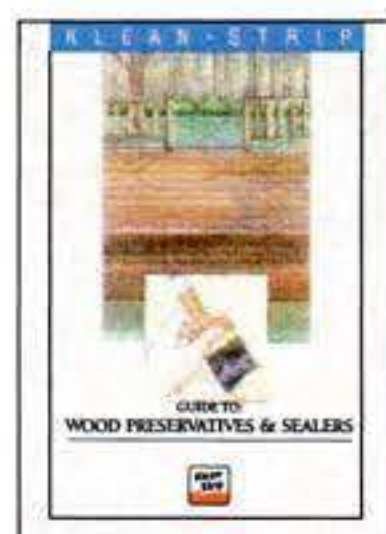
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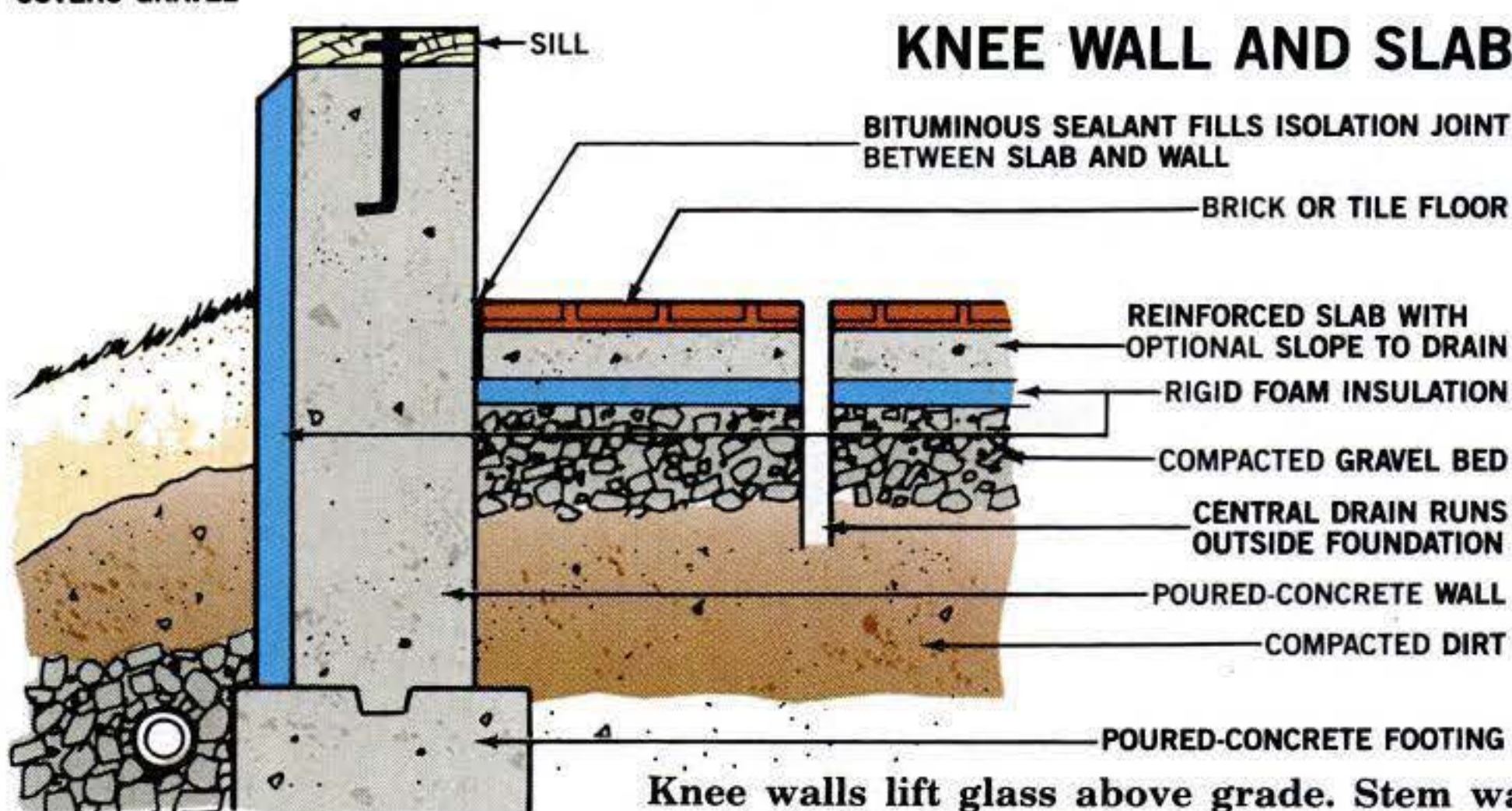
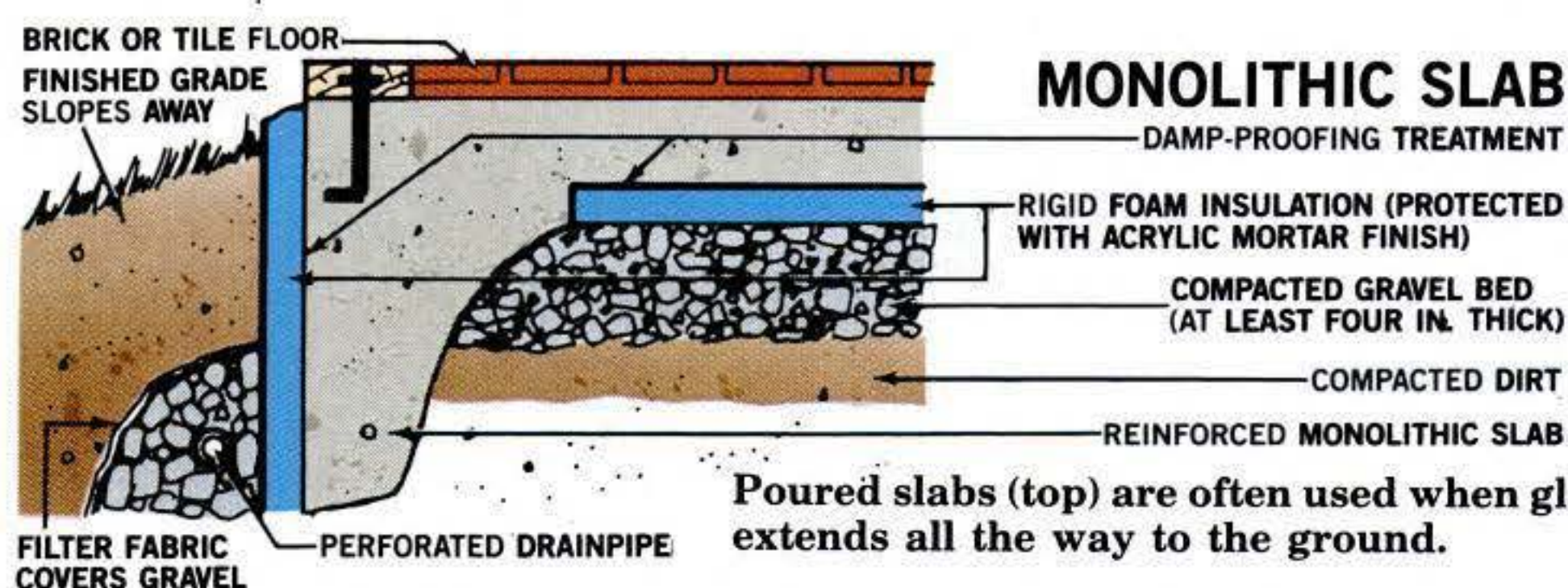
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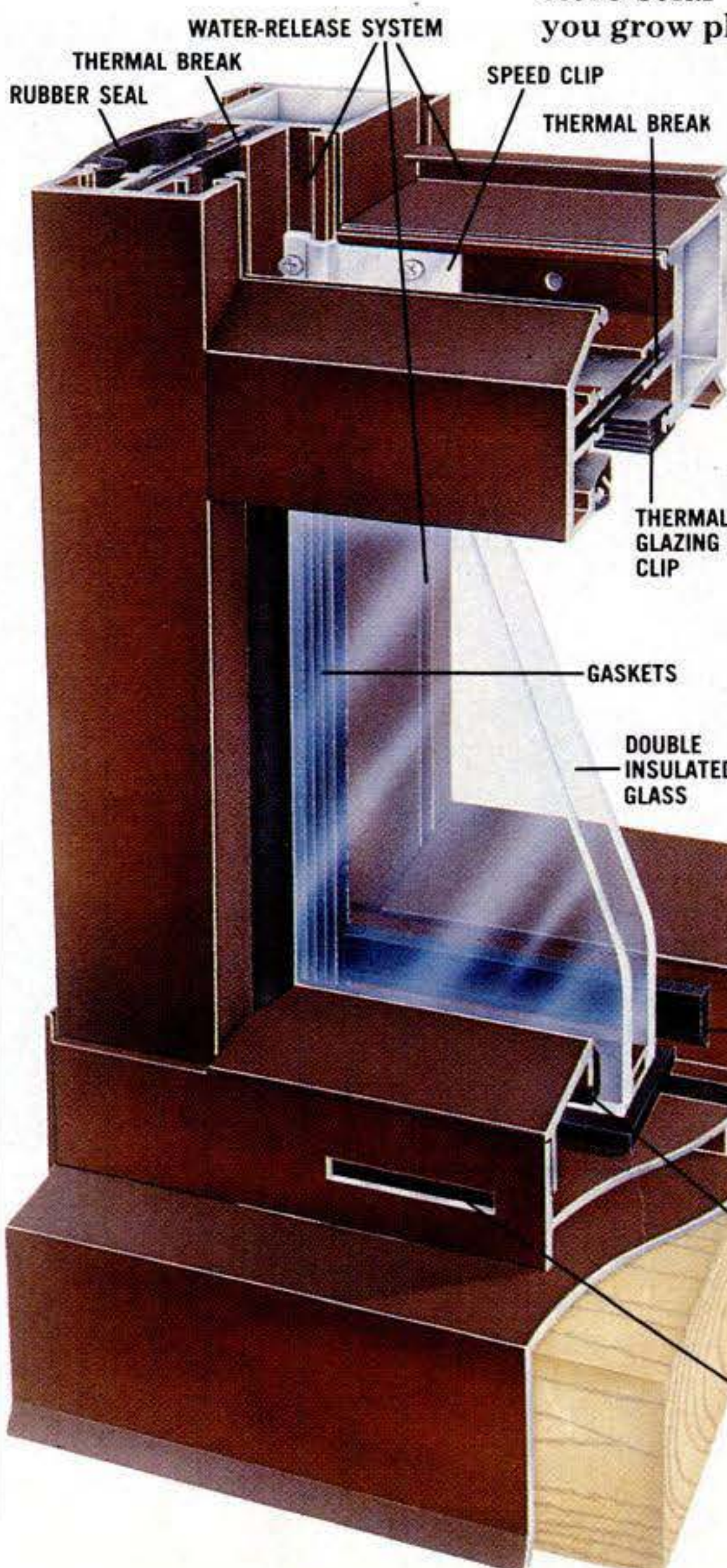
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DRAWINGS BY ED LIPINSKI



Florian Greenhouse's drawing shows the assembly system for its Sierra Room sunspace. Gaskets and two-sided tape hold glass in place, but prevent glass-to-metal contact. A stainless-steel speed clip makes it easy to put the unit together, but the glazing clip that secures the glass is made of nylon, which prevents heat from traveling through the frame by metal-to-metal transfer. That's the purpose of the thermal breaks, which are also made from a non-conductive material. A rubber seal that insulates gable ends also acts as a thermal break. Like all of the better greenhouses, the Florian unit has tracks that carry away condensation. The weep channel along the sill is sloped so water automatically drains out the weep holes.

It's also essential to look carefully at the instructions beforehand. Manufacturers like The Sun Co. make your job easier by numbering parts to match step-by-step directions. But some companies sell kits that are extremely difficult for a do-it-yourselfer to assemble, warns Ed Overberger, vice president of Creative Structures, a sunspace manufacturer. "I would look for a professionally produced installation video, one that shows you details," he recommends. He estimates that phone calls from confused buyers have dropped by three-quarters since his company introduced a video a year ago. Ask to borrow or rent the video and manual, and make sure you feel confident about putting the sunspace together before you buy it.

For an extra fee some companies will send a carpenter to your home to check the alignment of the sunspace's sills before you begin erecting the framing. Ask the dealer if such a service is available.

One way to assess the difficulty of building a sunspace is to check references. "Get a list of satisfied customers and inspect a finished sunspace," says Overberger. "I would be skeptical of a dealer who can't give you the name of another do-it-yourselfer who has built a sunspace."

Once you've found a sunspace that's properly engineered, and you're certain you can build it with the instructions provided, you need to make some other decisions:

- **Purpose and size.** A room used to grow plants has different glazing and ventilation requirements than a living area. If you don't need a fancy room, you might want to look at sun porches like those made by Vegetable Factory and Solar Resources. "Not everybody can afford twelve or twenty thousand dollars for a glass structure," says Stephen R. Kenin, president of Solar Resources. His company's Solar Rooms, which sell for under \$2,000, switch from solar collectors in winter to screened porches in summer.

- **Foundation.** Will you build it on a slab or construct a stem wall or knee wall? It's important to properly prepare the site in advance (see drawings and "Pro's Tips," this issue).

- **Framing.** Aluminum framing is almost always cheaper than wood. It usually comes in bronze, white, and mill-finished aluminum—but at least one homeowner has turned his greenhouse into a pinkhouse. Whatever the color, the metal should be anodized to prevent corrosion. Some aluminum structures have a baked-on enamel

Continued

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coating instead. If you choose one of these, make sure the coating is even, or the surface may crack and peel.

Wood systems may be more attractive than aluminum, but they are usually more difficult to install and maintain. Laminated beams, for example, may need occasional varnishing.

Both aluminum- and wood-framed sunspaces can be made watertight. The sunspace should not only keep out rain and melting snow, but should also eliminate condensation that may accumulate on inside surfaces, notes Gilmer. Look for weep channels as a standard feature (see drawing). "Gutters located only between the lights of glass on the upper surface of the rafters are not sufficient," says Gilmer. What you need are gutters around all four sides of every light of glass, on the inside of the room, he says. The gutters should overlap so that water cascades from one to the next as it travels to drainage holes.

● **Style.** Pick a design and roof angle that blend well with the rest of your house. Many companies offer models with a variable roof pitch, making it easier to mate the sunspace with the side of your house.

● **Roofing.** A clear roof admits more light, but the sunspace may overheat if you don't install shades or screens. An opaque roof minimizes overheating and can be insulated, but won't give you a view of the sky. Make sure the roof is engineered to easily support the snow and ice load you expect in winter. Check to see that the design complies with local building codes.

● **Ventilation.** The type of glazing and accessories you choose will determine how well you can control the temperature and humidity inside the room. "The biggest mistake we've seen is people who purchase a sunspace, looking for a good deal, and they end up with only one door and one window [built into the room]," says Overberger. "And they are going to *bake*."

● **Cost.** Check whether your state offers energy tax credits—some still do. Ask local realtors whether the addition will increase the resale price of your home. Even if it won't, the sunspace may help attract buyers. And if it's properly designed, it can benefit your home's energy budget.

The accompanying table lists some companies who make prefabricated sunspaces. Before you order a kit, write for more detailed information. **P S**

SUNSPACE-KIT MANUFACTURERS

No. of residential styles	Sizes (ft.)			Frames		Eaves	Roofs	Foundations	Price (\$)	Construction time ²
	Height	Length	Projection	Aluminum or steel	Wood					
1	8'	10'5 3/4"-36'7 3/8"	7'8 1/4"-11'7"	✓	✓	✓	✓	✓	4,981-15,260	8-12 hours
4	6 1/8"-10'	13'-any	3'-11'	✓	✓	✓	✓	✓	7,000-18,000	1-2 days (delivered fully assembled)
2 ³	2'8"-12'3 1/4"	7'11 1/2"-52'1 1/4"	1'9 7/8"-23'8 1/8"	✓	✓	✓	✓	✓	30-80 ⁴	2-3 days
4	7'-20'	3'-any	3'-65'	✓	✓	✓	✓	✓	40-60 ⁴	32 hours ⁵
5 ³	5'6 3/4"-7'3/4"	6'7 1/4"-36'7 1/4"	3'5 1/4"-12'5 1/4"	✓	✓	✓	✓	✓	2,000 ⁶	16-24 hours
4	5'-27'	3'-any	1'8"-27'	✓	✓	✓	✓	✓	5,000 ⁶	2 days
6	5'6"-30'	5'6"-any	2'-65'	✓	✓	✓	✓	✓	2,000 ⁶	4 days ⁵
8 ³	5'4 1/8"-20'6"	8'1 1/8"-32'3 3/8"	2'4 3/4"-21'5"	✓	✓	✓	✓	✓	2,500 ⁶	7 days
6	8'-20'	12'6"-any	4'-17'	✓	✓	✓	✓	✓	6,000-20,000	16-48 hours
4 ³	3'-30'	3'-any	3'-20'	✓	✓	✓	✓	✓	50-70 ⁴	2 days for 10'-by-20' unit
9	10'-14'	11'-24'	8'-16'	✓	✓	✓	✓	✓	5,189-17,166	80 hours
16	4'-17'	8'-any	3'-16'	✓	✓	✓	✓	✓	1,500-12,000	8-40 hours
6	7'1"-11'	3'-any	4'1"-12'10"	✓	✓	✓	✓	✓	3,000 ⁶	3 days
3	6'8 5/16"-9'9 5/16"	8'-22'	3'-11'	✓	✓	✓	✓	✓	2,550-12,554	12 hours ⁵
many ³	2'6"-30'	any	1'-30'	✓	✓	✓	✓	✓	3,000 ⁶	6 hours ⁶
4	6'-12'	2'11 5/8"-any	2'3 1/8"-14'9"	✓	✓	✓	✓	✓	1,725-12,800	32 hours
8 ³	8'6"-19'	8'-any	4'-25'	✓	✓	✓	✓	✓	4,800 ⁶ (8,000-12,000 avg.)	2 days ⁷
1	8'	12'-40'	7'	✓	✓	✓	✓	✓	1,710	2 days
4 ³	4'-18'	2'6"-any	2'-13'6"	✓	✓	✓	✓	✓	40-60 ⁴	1 hour per 3.5 sq. ft. of glass
5	8'-9'4"	10'-24'	6'-10'	✓	✓	✓	✓	✓	3,300-10,000	24-36 hours
many ³	any	10'-any	4'-16'	✓	✓	✓	✓	✓	5,000 ⁶	2-3 days
4 ³	4'-16'	3'-any	3'-18'	✓	✓	✓	✓	✓	2,000 ⁶	20-40 hours
2	6'-16'7"	any	2'8"-15'4"	✓	✓	✓	✓	✓	2,500-15,000	24 hours ⁵
3	7'6 1/2"-8'1 1/2"	7'6"-any	5'1 1/2"-10'1 1/2"	✓	✓	✓	✓	✓	1,200-7,000	8-15 hours
1 ³	7'2"-10'2"	5'-any	8'6"-10'6"	✓	✓	✓	✓	✓	3,500-15,000	48 hours
1 ³	7'-12'	4'-any	4'-40'	✓	✓	✓	✓	✓	20-40 ⁴	2-4 days
4 ³	4'7"-28'	3'4"-any	1'8"-25'	✓	✓	✓	✓	✓	1,000 ⁶	12 mins. per sq. ft. of glass
3 ³	4'6"-14'	any	1'8"-20'	✓	✓	✓	✓	✓	1,500 ⁶ (7,500 avg.)	2 days ⁵
2 ³	7'10"-12'9"	any	6'-12'	✓	✓	✓	✓	✓	1,395-50,000	1-14 days
4	4'8 1/8"-11'6 1/4"	any	1'8"-13'7 5/8"	✓	✓	✓	✓	✓	1,125 ⁶	3 days
1	7'5 3/4"-10'5 3/4"	3'-any	3'2 3/4"-15'2 3/4"	✓	✓	✓	✓	✓	35 ⁴	2-3 days

Manufacturer

Advance Energy Technologies
Solar Dr., Clifton Park NY 12065

Brady & Son
97 Webster St.
Worcester MA 01603

California Solariums
5300 N. Irwindale Ave., Irwindale CA 91706

Classic Solar Design
3 Steuben Dr., Jericho NY 11753

Creative Structures
1765 Walnut Lane, Quakertown PA 18951

Everite Greenhouses
9305-H Gerwig Lane, Columbia MD 21046

Floriant Greenhouse
64 Airport Rd., West Milford NJ 07480

Four Seasons Greenhouses
5005 Veterans Memorial Hwy., Holbrook NY 11741

Freedom Sunspace
RD 5, Box 172, Freehold NJ 07728

Gammans Industries
Box 1181, Newnan GA 30264

Habitat
123 Elm St., South Deerfield MA 01373

J. A. Hearing Co. (Janco)
9390 Davis Ave., Laurel MD 20707

Lindal Cedar Homes
4300 S. 104th Pl., Seattle WA 98178

ODL Inc.
215 E. Roosevelt Ave., Zeeland MI 49464

Regal Manufacturing Co.
Box 14578, Portland OR 97214

Skytech Systems
Box 763, Bloomsburg PA 17815

Solar Additions
Box 241, Greenwich NY 12834

Solar Resources
Box 1848, Taos NM 87571

Solarium Systems International
5340 Shoreline Blvd.
Mound MN 55364

Sturdy-Built Greenhouse Manufacturing Co.
11304 S.W. Boones Ferry Rd., Portland OR 97219

Sun Room Co.
322 E. Main St., Leola PA 17540

Sun Room Designs
Depot & First Sts., Youngwood PA 15697

Sunbelt Solar Products by Sussman
109-10 180th St., Jamaica NY 11433

Sunglo Solar Greenhouses
4441 26th Ave. W., Seattle WA 98199

Sunlite Industries
3852 Hawkins N.E., Albuquerque NM 87109

Sunmaster Homes & Additions
Box 1052, Alamosa CO 81001

Sunspace, Inc.
6601 Amberton Dr., Baltimore MD 21227

Sunshine Rooms
Box 4627, Wichita KS 67204

Texas Greenhouse Co.
2425 White Settlement Rd., Fort Worth TX 76107

The Sun Co. Solar Design & Construction
14217 N.E. 200th St., Woodinville WA 98072

Vegetable Factory
71 Vanderbilt Ave., New York NY 10169

Notes: ¹Not including free-standing greenhouses or commercial units; ²for average-size room, not including site preparation or finishing; ³variable roof pitch on some models; ⁴per square foot; ⁵with two workers; ⁶and up; ⁷with three workers

DRAWING BY BRENDA BOOTH

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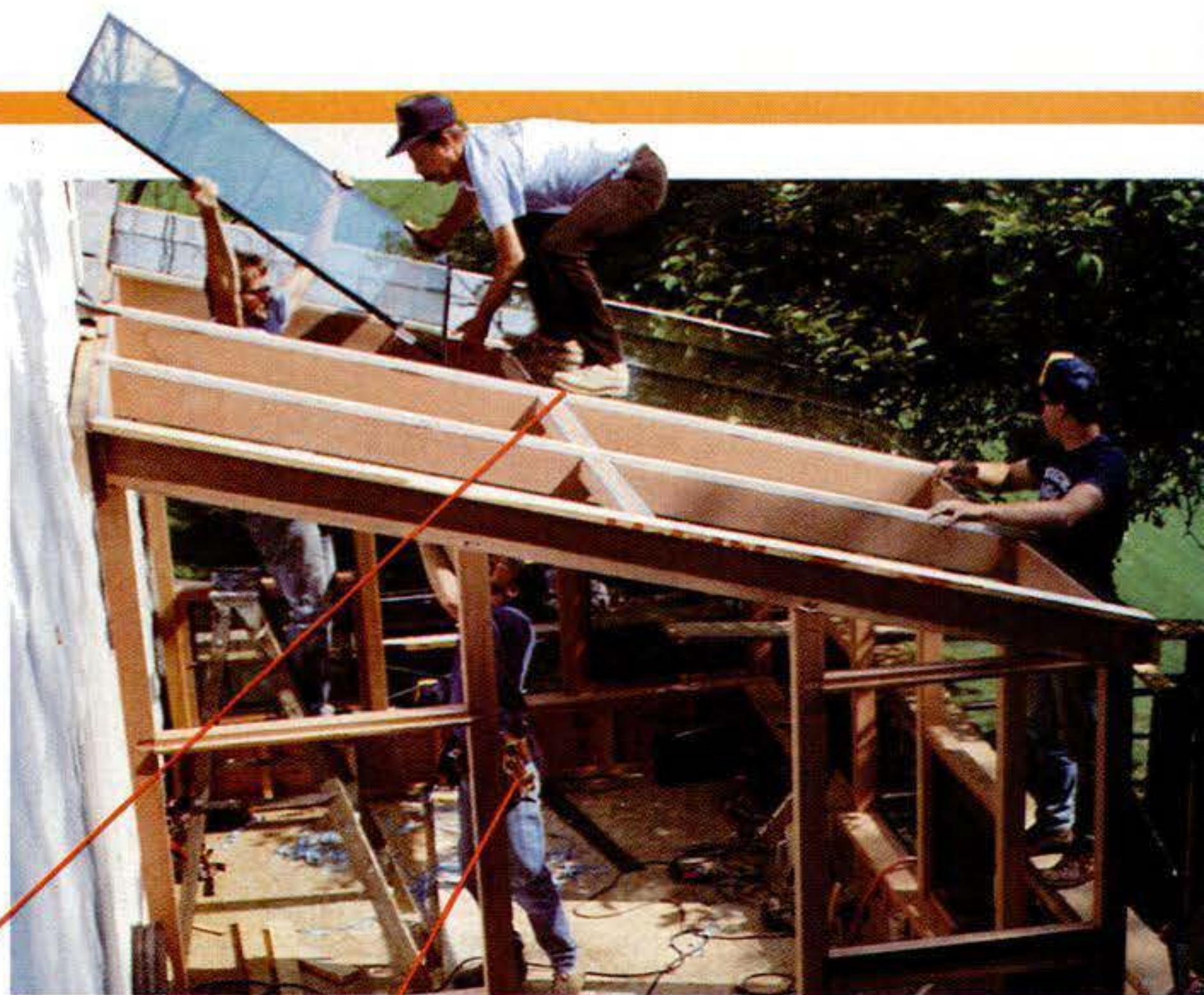
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Assembly: Pro's tips

Thinking about erecting a kit sunspace? **POPULAR SCIENCE** followed one contractor through a step-by-step assembly of a handsome red-wood-framed unit and got some important tips for ensuring a successful project.

By **NAOMI J. FREUNDLICH**
Photos by Robert Werber

The Jancovics couldn't have asked for a more pastoral setting for their eastern Pennsylvania home. Their backyard slopes down to a babbling brook, and leafy oaks offer dappled shade. It's the perfect spot for a sunspace, they thought, except for one thing: Because the house sits on a hill-ock a second-story sunspace was the only option. This was no problem for contractor Bob Marx of Sun Rooms of Lehigh Valley (Bath, Pa.). He built an elevated platform to hold a model 9-15-58 sunspace from Creative Structures Inc. (1765 Walnut Lane, Quakertown, Pa. 18951), extending the understructure 15 feet to create a second-story deck. I covered the first day's work, asking questions so I could pass along tips to anyone thinking of erecting a similar kit. **PS**



Do not stand on the glass during set in. Pros do it, but sometimes break through panes. If it's unavoidable, wear clean soft-soled shoes.

Once glass is in, a tedious process of weatherproofing—caulking and sealing—follows. Don't race or skimp: It's the key to final success.

Erect a knee wall with temporary braces before beginning the sunspace assembly.

It's important to lay the sill level and square. Our pros lay a bead of caulk between the knee wall and sill before tacking it temporarily.



This kit from CSI comes with pre-tenoned beams that fit pre-cut mortises. As with most kits, each piece is numbered to coincide with steps in the instruction manual. Be sure to count all the pieces before you start assembly and lay them out in the order they'll be needed.



Don't expect your house to be plumb or level. You might have to shim out the wall plate to make sure it's parallel with sill.

Before anchoring the sill make sure it is positioned correctly by checking the plumb of rear posts with a level.



Use a rubber mallet when setting posts to avoid damaging tenons. The mallet should also be used on all exposed surfaces to keep the redwood unscarred.

Have a utility knife on hand in case any of the joints are too tight and need to be shaved.



Use a bar clamp to draw rafters snug when attaching roof purlins and spacers. Pros toe in sheet-metal screws without pre-drilling.

It's extremely important to make a final check of square when the basic frame is complete, with rafters and front posts attached. Check with a carpenter's square and level, and measure accurately from opposite corners for identical dimensions. At this stage the sill can still be shifted to correct any problems. If the frame is not square, the glass will not go in.



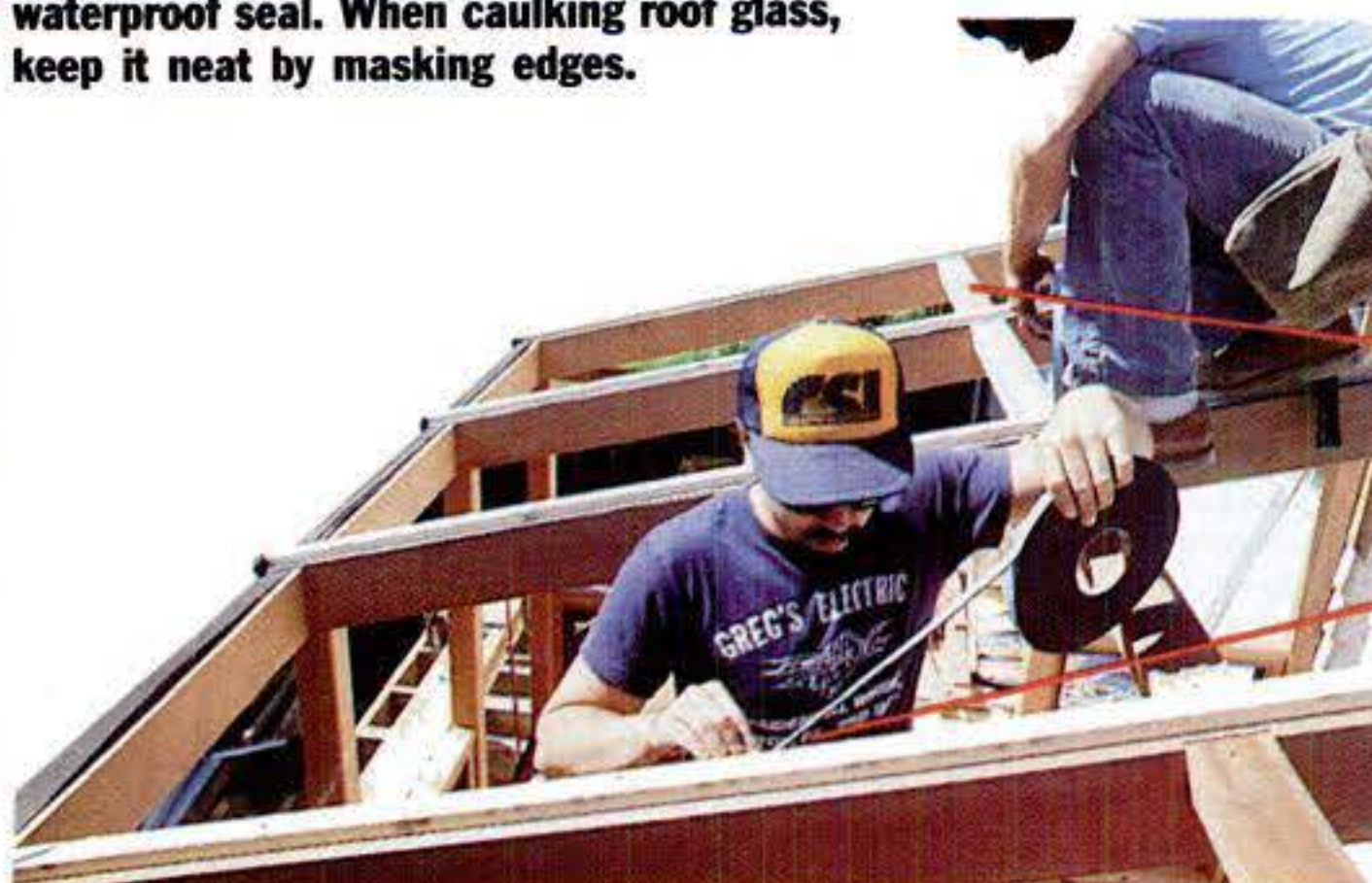
Mahogany window units (mahogany is harder than redwood) come with the CSI kit and fit within the frame. Remove snap-in screens during assembly to avoid damage.



Note the bridge across the door frame for extra support. It is cut flush with the opening before the door is installed.

Apply a continuous bead of black silicone caulk around all awning windows to form a waterproof seal. When caulking roof glass, keep it neat by masking edges.

Crank window open before nailing in place. Use nails to attach windows to top framing to avoid splitting. The bottom is screwed in place.



Nailed-on spacers provide the rabbet in which the roof glass fits. Double-stick foil-backed butyl tape is pressed into place on edges of rafters and purlins before glass is lowered into the rabbets.

To keep the adhesive face clean, the foil is stripped back as the glass is lowered onto the tape.

Get smart about glazing

GLAZING CHOICES—BY THE NUMBERS

Type	U-value ¹ (winter)	R-value ² (winter)	Shading coefficient ³	Visible light trans. (%) ⁴	UV trans. (%) ⁵	Cost/ comments
Single glass						
Clear	1.12	0.89	1.00	90	80	Sunspaces are seldom made with single glass.
Tinted	1.12	0.89	0.85	69	43	
Reflective	1.12	0.89	0.51	27	15	
Double glass						
Clear	0.50	2.00	0.89	82	64	Average cost for a sunspace with clear insulating tempered glass might be \$25 per sq. ft. (psf) of glazing. Tinted glass should add around \$1.80 psf to that price; reflective adds around \$4.70 psf.
Tinted (bronze)	0.50	2.00	0.73	63	34	
Reflective (bronze)	0.50	2.00	0.41	25	12	
Low-e glass⁶						
Clear	0.31	3.20	0.76	72	49	Low-e glass adds about \$5 psf of glazing to the price of a sunspace (vs. clear insulating glass).
Tinted (bronze)	0.31	3.20	0.61	55	31	
Heat Mirror⁷ (two 5/16" spaces)						
88 (with clear glass)	0.26	3.85	0.70	71	34	Heat Mirror glazing should add about \$5.90 psf of glass to the price of a sunspace (vs. clear insulating glass).
66 (with tinted glass)	0.25	4.00	0.41	42	9	
44 (with reflective glass)	0.25	4.00	0.16	12	n.a.*	
Laminated glass	1.08	0.93	0.82	79	1	Laminated glass (annealed) is about three times the price of single tempered glass.
Polycarbonate (1/4")⁸						
Clear	0.96	1.11	1.02	82	0	Polycarbonate is more costly than single tempered glass. But curved eaves of it (a typical use) may be about half the price of curved eaves of tempered glass.
Tinted (gray/bronze)	0.96	1.11	0.79	50	0	
Structured polycarbonate (8-mm)^{8, 9}						
"Clear"	0.64	1.78	0.96	82	0	Structured polycarbonate costs more than single tempered glass, but much less than tempered insulating glass.
Tinted (gray/bronze)	0.64	1.78	0.61	25	0	
White	0.64	1.78	0.53	20	0	
Acrylic (1/8")^{8, 10}						
Clear	1.06	0.94	0.98	92	n.a.	Monolithic acrylics are 25–30% less than polycarbonates. Use only those appropriate for sunspace glazing.
Tinted (bronze)	1.06	0.94	0.61	27	n.a.	
Structured acrylic (16-mm)^{8, 10}						
"Clear"	0.58	1.72	0.98	87	n.a.	Structured acrylic may cost more than structured polycarbonate because a heavier gauge may be required.
Tinted (bronze)	0.58	1.72	0.79	52	n.a.	
White	0.58	1.72	0.38	20	n.a.	
FRP						
Single "clear" ⁸ Kalwall panels ¹¹	1.14 0.24	0.87 4.16	0.98 0.18	90.5 20	17 1	Premium "clear" FRP is similar in cost to monolithic acrylic. It is used for horticultural greenhouses and hot-tub enclosures. Kalwall panels are \$10–\$20 psf (wholesale).

Specifications assume 1/8" glass lites and 5/8" air spaces, unless otherwise noted. All values for tinted, reflective, and white glazing represent products commonly used in residential sunspaces, but all are available in a range of opacities. Data given for clear, tinted, reflective, laminated, and low-e glass are from PPG Ind. and represent typical production values for vertical glazing.

NOTES: ¹U-value is the heat-transfer rate through materials, measured in Btu/hr./sq.ft./deg. F temperature difference. Winter nighttime U-values are calculated assuming an outdoor temperature of 0°F, an indoor temperature of 70°F, and a wind velocity of 15 mph. ²R-value (resistance to heat flow) is the reciprocal of the U-value. ³Shading coefficient compares the total solar heat gain through any other glazing with that through a single pane of 1/8" glass—which has a shading coefficient of 1. ⁴Visible light transmission indicates the percentage of the visible spectrum that passes through the glazing. ⁵UV (ultraviolet) transmission is given because the sun's shortwave UV energy fades fabrics. ⁶Low-e glass data are for PPG's Sungate 100; other low-e products may differ. ⁷Heat Mirror film comes in three types, as noted; all can be combined with different glass types. Data shown represent the common range of solar optical qualities available. ⁸A range of thicknesses is used for sunspace glazing; also used for double glazing. Consult glazing or sunspace manufacturer for specifications. ⁹Sold in 6-mm–16-mm thicknesses; 8-mm is used for curved glazing. Data represent GE Plastics' Thermoclear panels. ¹⁰Data are for Exolite panels from Cyro Ind. ¹¹Available in many thicknesses and opacities; data given represent 2 3/4" size. *Not available

DRAWING BY BRENDA BOOTH

When the walls—and perhaps the roof—of a room are windows, the glazing you choose is critical. You'll need to consider comfort, energy efficiency, aesthetics, light transmission, safety, cost, and more.

By V. ELAINE GILMORE

At the National Association of Home Builders show in Dallas last winter, I paused at the Four Seasons Solar Products booth, and Donald Staib, the company's national accounts manager, promptly beckoned me into a long sunspace flanked by a bank of heat lamps.

I passed into the first bay (glazed with double insulating glass, said the sign) and was overwhelmed by the heat. I scurried on to bay two (bronze-tinted double glass) and found an improvement to the ovenlike environment. Finally, in bay three the temperature was relatively comfortable. It was glazed with Heat Mirror, a triple sandwich with two sheets of glass and two air spaces surrounding a low-emissivity (heat reflecting) polyester film.

It was a graphic demonstration of how important the choice of glazing can be in a room that is mostly windows. And what a choice there is: not only the different glasses Four Seasons demonstrated, but several others as well. And many kinds of plastics. What glazing is best for your sunspace? That depends on climate, design and orientation of the room, and what you expect from it. Your choices also may

Continued

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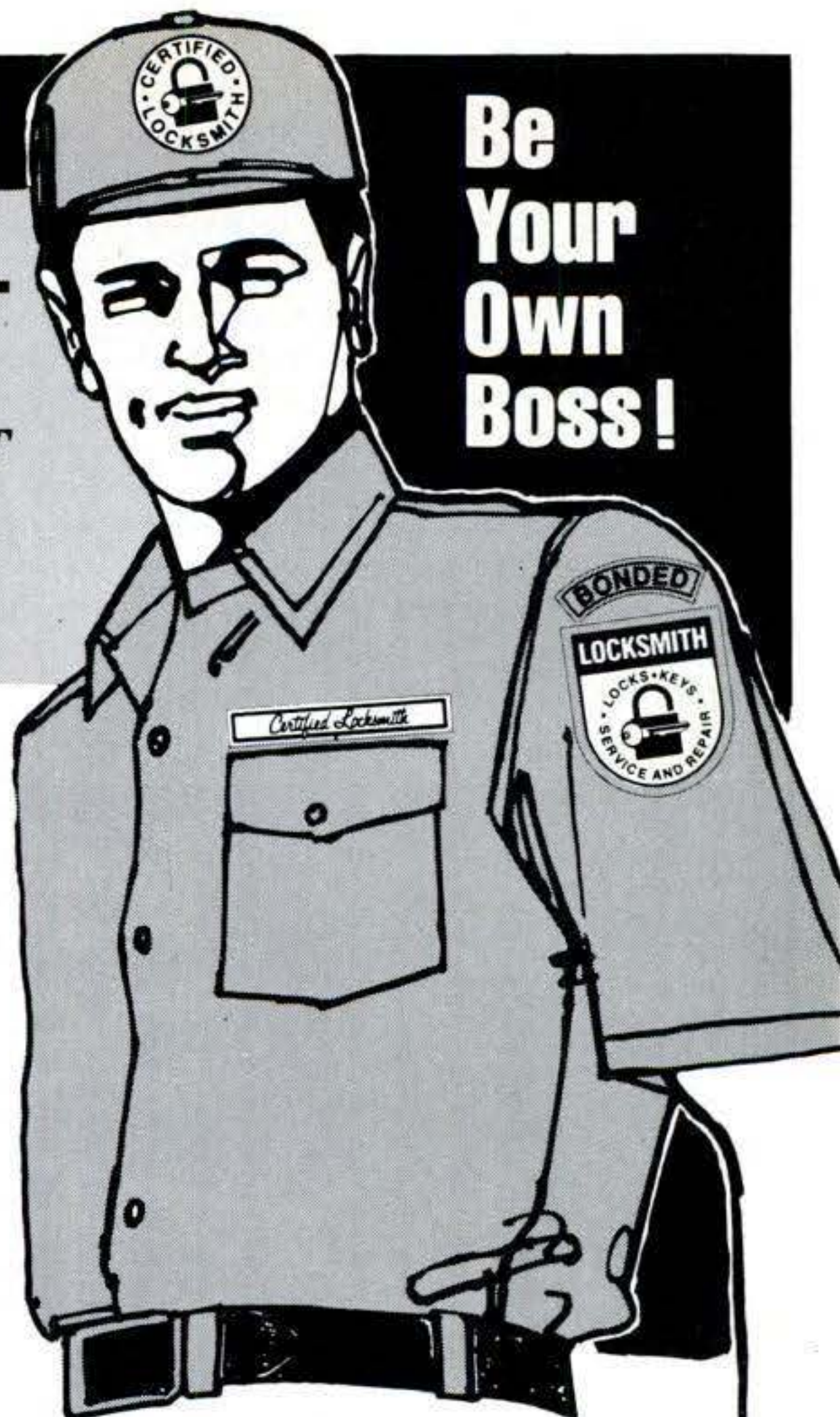
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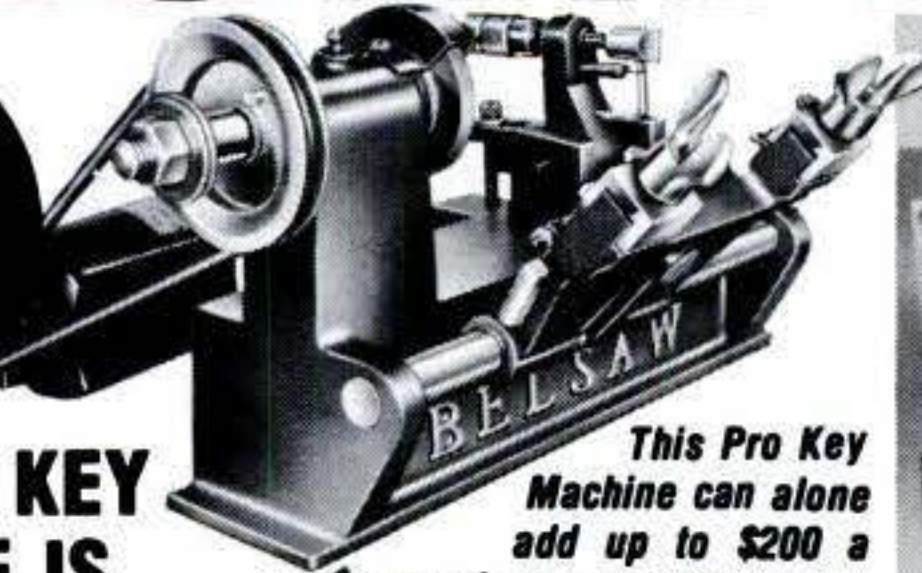
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be narrowed by your local building code—and your pocketbook. Once you understand the considerations, the data in the table on a previous page can help you choose.

The great escape

Glazing has a reputation as a great leaker of heat. Here's why: While an ordinary 2×4 stud wall with batt insulation has an R-value (resistance to heat flow) of about 11, a single

pane of 1/8-inch glass ranks a measly R-0.89. Add a second pane of glass with a 5/8-inch air space between the panes, and it creeps up to R-2—still low enough to lose heat like mad on a cold winter night.

Much of the heat that escapes will be radiant heat—the long-wave infrared radiation emitted by everything in the room. Stand near a window on a cold night, and you may feel chilly, even if the air temperature is

warm. That's partly because you're radiating heat to the window. Glass is nearly opaque to most infrared, so it absorbs your body heat and reradiates it, mostly outside.

Low-emissivity double glazing (see sidebar: Talking Glazing) has a higher R-value than standard double glazing because it reflects much of the radiant heat. With a 5/8-inch air space and a low-e coating on one of the two panes the R-value generally ranges from 2.5 to 3.2, depending on the type of low-e coating ["Superwindows," March '86]. With Heat Mirror, the low-e film Four Seasons demonstrated, you can have triple-glazed windows that weigh no more than double windows, yet have an R-value of 3.8 to 4 (with two 5/16-inch air spaces).

Low-e glazing has other advantages: Its interior surface stays warmer in winter. "When it's seventy degrees [F] inside and zero outside, low-e glass will have a room-side surface temperature of fifty-five degrees," says William Uhl Jr., residential construction marketing manager for PPG Industries. "Standard double glass would be forty-four degrees, and single glass would be fifteen degrees on the inside. With low-e glass the relative humidity in the room can be sixty percent under those conditions, and no condensate will form," Uhl adds. The higher surface temperature of the glass also makes the room more comfortable.

Low-e glazing is a benefit in summer too. It reduces radiant heat gain because it reflects heat radiated from outdoor surfaces.

But low-e glazing is more expensive

Talking glazing

LOW-E (EMISSIVITY) GLASS has a micron-thin layer of metal or metal oxide on one side. The coating reflects much of the infrared radiation but readily transmits visible light.

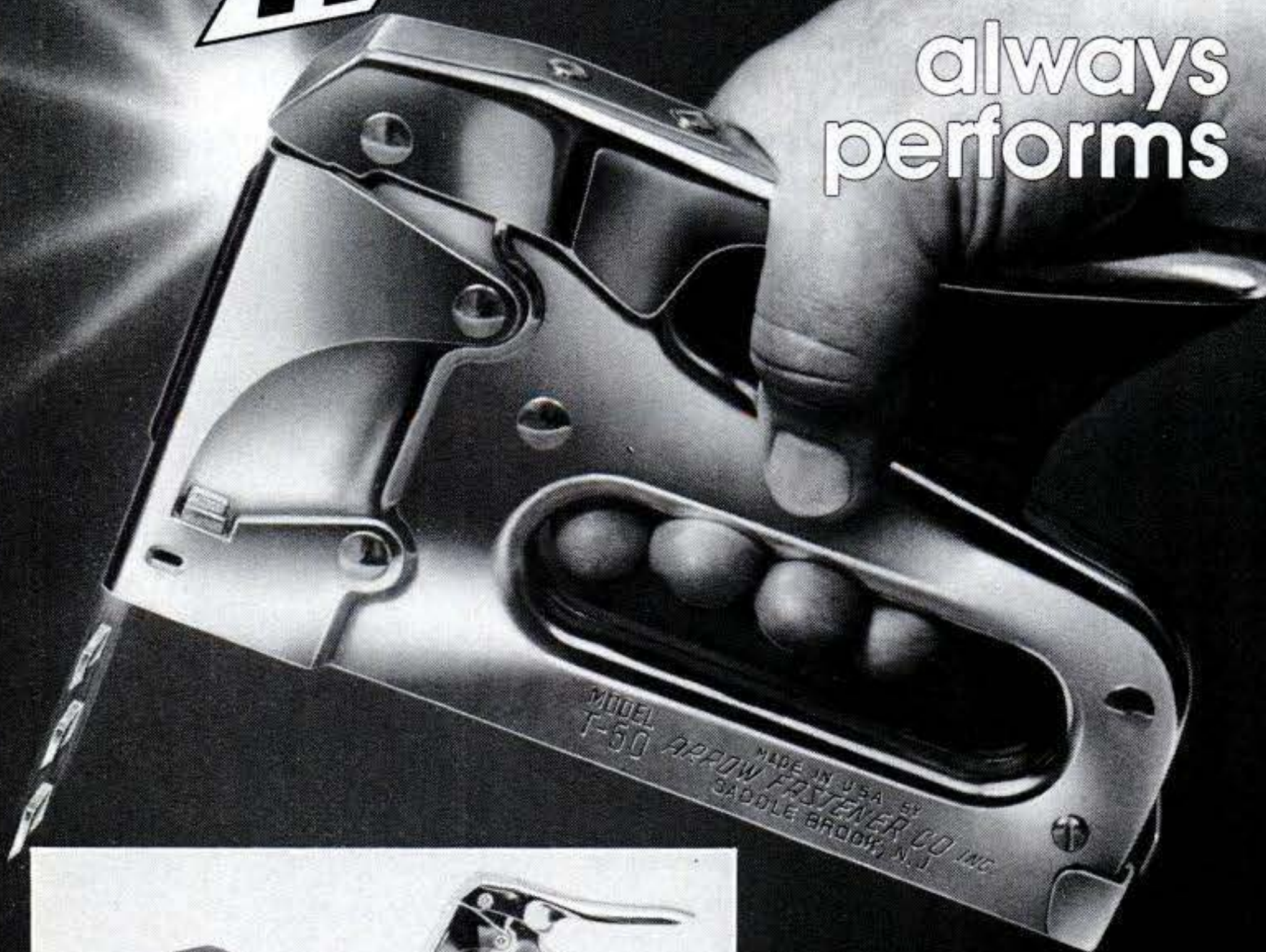
EMISSIVITY refers to the heat-emitting (radiating) propensity of a surface. The emissivity number compares a given surface with a perfect radiator, called a blackbody (emissivity, 1). Ordinary window glass has a high emissivity, meaning that it absorbs—then emits—most of the radiant heat that strikes it. With a low-e coating the glass reflects the heat instead. All else being equal, the lower the emissivity, the lower the U-value (thermal conductance—see notes below table).

HEAT MIRROR, a polyester film made by Southwall Technologies, has a low-e coating on one side. It is used as the center lite in triple, or even quadruple, glazing. Glass is used for the outside lites. The additional air spaces lower the U-value of the window.

REFLECTIVE GLASS has a mirrorlike metallic coating that reflects solar energy, including visible light. It is often used on office buildings and for overhead glazing.

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than standard double glazing. Is it a good buy? All else being equal, the more extreme your climate, the better a buy it is likely to be. Andersen Corp. did a study of sunspaces in 16 cities across the country, and found that in all a properly designed sunspace could be more energy efficient than a standard room of the same size. With low-e double insulating glass that remained true, even when the sunspace faced north.

How much of a good thing?

Heat loss is only part of the energy picture in a sunspace. You should also consider the amount of solar energy the glazing lets in. It is because of the solar gain that well-designed sunspaces can be better energy performers than conventional rooms.

But the sun also can be the enemy in sunspaces: Overheating is a common complaint. The "shading coefficient" column on the table ranks the glazings according to the amount of solar energy they admit.

In general, the colder your climate and the more heat you intend to reap from the sun, the more you need to consider a glazing with a relatively high shading coefficient.

The hotter and sunnier your climate, the more important is a lower shading coefficient. "In southern locations tinted or reflective glass is very desirable," notes Dr. Harold Gray, executive director of the National Greenhouse Manufacturers Association. "Otherwise, your sunspace can become unbearable in summer." But beware of glazings with a low shad-

ing coefficient if you want to grow light-loving plants, Gray warns. "If you just want some green plants for decoration there's very little problem. But with some flowering and fruiting plants, watch out." He advises looking for a shading coefficient above 0.70 or 0.80 if such plants are in your plans.

One popular option is to choose a lower shading coefficient for overhead glazing and a higher number for ver-

tical glazing. Thus in summer when the sun is high in the sky (striking the overhead glazing more directly), more of it will be blocked. But in winter when the sun hangs low, more energy will pass.

The "visible light transmission" column in the table gives the percentage of sunlight in the visible spectrum each glazing transmits, and thus indicates how bright the room will be.

[Continued on page 86]

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TINTED GLASS absorbs more solar energy than clear glass. Heat that is absorbed is radiated in all directions. Tinted and low-e glasses are often combined into high-performance windows for warm climates.

LAMINATED GLASS sandwiches a tough plastic film of polyvinyl butyral resin between two sheets of glass. If it breaks, the film holds the shards. (Laminated glass is used for car windshields.) It does not resist breakage better than ordinary glass of equal thickness, however (unless tempered glass is used).

TEMPERED GLASS has been heat treated to increase its strength. Most sunspace manufacturers who use glass provide tempered glass because of its improved safety.

STRUCTURED PLASTIC SHEETS—made of polycarbonate or acrylic—are double-skinned assemblies with internal ribs a fraction of an inch apart. They combine structural rigidity and light weight.

KALWALL PANELS are two skins of fiber-reinforced plastic (FRP) with a ribbed internal structure and insulation (similar to angel hair for Christmas trees) between the skins. —V. E. G.

Finding and erecting the right sunspace for your house is only half the battle. Once you've put your solarium up, you have to keep it cool and livable on warm summer days, and warm enough to enjoy on cold winter nights. Here's a selection of insulating shades, sun screens and shades, floor tiles, and ventilating systems to make your sunspace as cozy as the rest of your house.

Outfit your sun-space

By TIMOTHY O. BAKKE



The newest addition to your household has finally arrived, shiny, new—and naked to the world. How do you dress it to protect it from the hot sun? Or keep it from getting too cold? What's the best way to keep it from getting too dirty, and to make sure it gets plenty of fresh air? This new arrival has special needs you may not have encountered before.

Of course, this "new arrival" is the almost-all-glass sunspace you've just added to your house. And it *does* have unusual requirements that demand the right accessories, depending on where you live—how hot or cold it gets—and how you'll use the new room. But if you outfit your sunspace with the right options, it will reward you with countless hours of "outdoor living" enjoyment.

A decade ago the sun room was used primarily as a greenhouse and, through solar gain, as an auxiliary heat source. As such, the concept of thermal mass and advanced technol-

No-hands control: Comfortex Corp.'s Smart Shades use remote-controlled solar-powered motors to power the tracked rail-and-drive operating system. The shades use Duette pleated fabric to provide translucent shading in summer and thermal efficiency of between R-3 and R-4.

ogies like phase-change materials had been of utmost importance. Times change, however.

"We see sun rooms used primarily as living spaces today," says Volker Schmidt, an engineer for Four Seasons, a large manufacturer of sunspaces. "So things like phase-change salts are rarely used because they are bulky and difficult to modulate. Solar gain and efficiency as a heat source don't carry the importance they used to."

"There are five basic things to consider when you accessorize a sun room intended as living space," says Dr. Harold Gray, director of the National Greenhouse Manufacturers Associa-

tion: "overheating in summer; retention of heat, especially at night during the winter; maintaining adequate ventilation and moisture levels; providing thermal mass for some solar gain as well as a carefree floor, especially if you are planning to house a lot of plants; and providing for supplementary heat in areas with cold winters." There are many products you might buy to deal with any of these situations, but first you have to define your needs.

You've got to wear shades

There are two approaches you might take to control the heat of the sun: erecting solar shades or screens either inside or outside the sunspace glazing. Solar screens are made of a specially woven fiberglass or plastic mesh that the manufacturers claim blocks the sun's heat and glare with minimal interference with your view. The screens are commonly installed outside the glazing.

"By being mounted outside the sun space glazing, solar screens cut off the sun's heat *before* it enters the room," says Mark Edwards of Phifer Wire Products.

A ventilating fan can be an important factor in keeping a sunspace from summertime overheating, but it must be weathertight and insulated for the wintertime. The TC 1000 ventilation system has an internal panel of foam insulation that is lifted up and out of the way for ventilating by a lifting motor, says Weather Energy Systems. It's then pulled down for a tight seal when the fan turns off.

Solar shades, on the other hand, are special translucent sun blockers, sometimes made of reflective material, that normally are mounted *inside* the glazing. (One firm, Pioneer Roll Shutter Co., makes shades that are intended exclusively for exterior use, however.) The shades are designed especially to be used in the sunspace environment, and they usually transmit ample light, but are said to block the sun's heat energy by either reflecting

or filtering the infrared radiation.

Protection against the summer sun, which travels at a high angle, is generally most effective on roof glazing and the upper areas of wall glazing. As an alternative to solar shades and screens, Accent Awnings makes a retractable awning that can be attached to the main house structure and extended over the sunspace roof only when needed. This protects the

Continued

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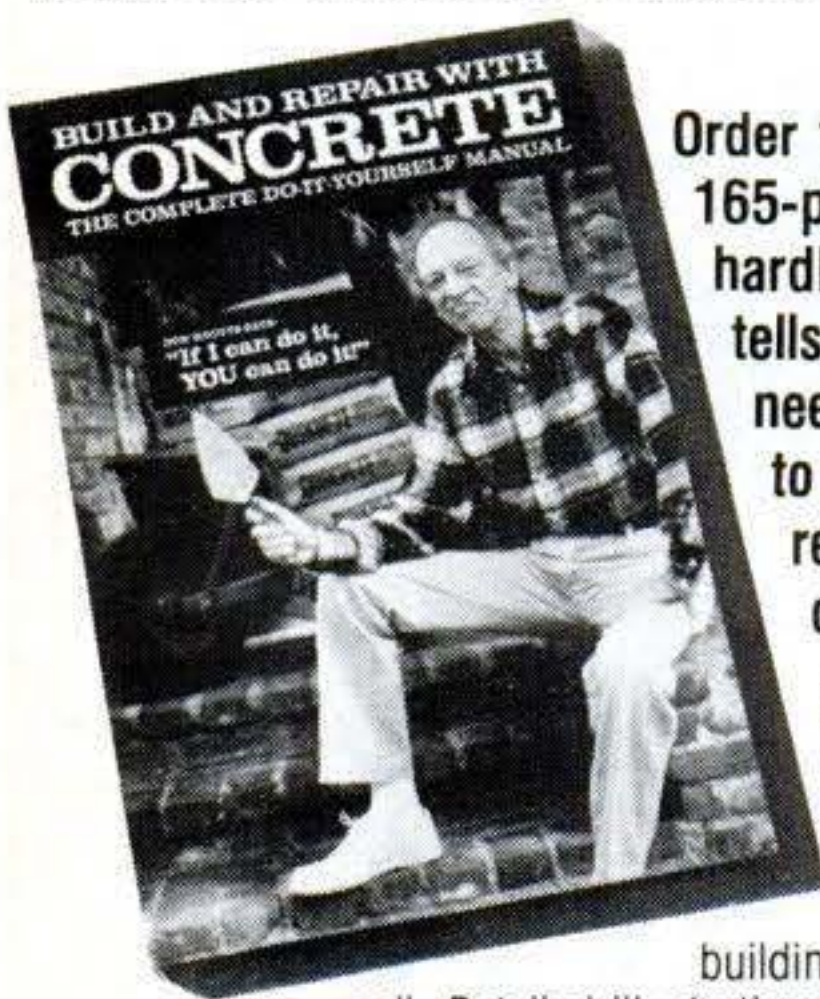


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With their wood-foam sandwich construction, the Boston Shutter & Door louvers and shutters provide an insulating performance of R-7, says the company. Exteriors are finished with white melamine laminate for summertime reflectance; interiors are finished in birch or red oak.

solarium during the hottest parts of the day without obstructing the view.

Keep the heat

At the opposite end of the spectrum, you may be concerned with winter thermal protection. Depending on where you live and how your sunspace is sited, you might achieve ample solar gain during winter to keep the sunspace comfortable, with enough extra energy to supplement your house's heat. Even if you do, you'll probably need supplementary heat for overcast days and night entertaining. Four Seasons' Schmidt suggests hooking up with your existing heating system as a separate zone if possible, or using a non-venting gas furnace, electric base-

boards, or an air-to-air heat exchanger if excess moisture is a problem in your sunspace.

Thermal shades, made of quilted or pleated fabric—usually with some kind of reflective backing—reduce heat loss through the sunspace glass. The shades generally run in a track under tension on the glazing frames to provide a tight seal and prevent sagging on curved or slanted areas. Most thermal shade systems offer a motorized option with remote control. Foam-filled shutters and louver panels like those from Boston Shutter & Door may be the best thermal protection in cold areas, but they are expensive and can be somewhat clumsy.

Breath of fresh air

Exhaust, or ventilating, fans get rid of the hot, stale air that can accumulate in sun rooms during warm weather. Supply fans are used during the winter to move the warm air of the solarium into the main house when

the sunspace is used as a heat source.

Ventilating fans may be mounted high at a gable end or in the roof of a sunspace and should be insulated in some way for winter. Supply fans are mounted between the house and the sunspace, and there should be two: one mounted high to provide heated air to the house and one mounted low to provide return air from the house to the sunspace.

"For any fan system to provide a positive gain to the house, the fan aperture must be closed at night," says Paul Raymer, president of Weather Energy Systems. "Otherwise more heat will be lost at night than will be gained during the day. And if the fans are controlled automatically, as with a thermostat, it's important that any aperture-closure system also be automatic so it will work when the homeowner is not home." Both ventilating and supply fans should be thermostatically controlled.

From the floor up

Most sunspaces are built on a concrete slab (see "Sun-sational Sun Rooms," this issue). Not only does this provide a good foundation, it also provides thermal mass that enables you to take advantage of the sun's energy in the winter.

"If you want to make the best use of thermal mass a dark-tile or brick floor is the way to go," says Robert Kleinhans, executive director of the Tile Council of America. "Not only is such a floor good for solar gain, but it is fade proof, durable, and waterproof, and requires little maintenance—important if you will have lots of plants in the sun room or if there will be a lot of indoor-outdoor traffic."

If you plan your sunspace carefully and choose your accessories to fulfill your needs, you'll add enjoyment and value to your house with a livable all-seasons room.

MANUFACTURERS OF SUNSPACE ACCESSORIES

Sunshades and screens: Accent Awnings, Box 777, Chester PA 19016; Castec, Inc., 7531 Coldwater Canyon Ave., North Hollywood CA 91605; Catalina Shading Systems, 230 E. Dyer Rd., Unit G, Santa Ana CA 92707; JMS Mfg., 717B Fellowship Rd., Mount Laurel NJ 08054; Phifer Wire Products, Box 1700, Tuscaloosa AL 35403-1700; Pioneer Roll Shutter Co., 155 Glendale Ave., Sparks NV 89431; Sol-R-Veil, 635 W. 23rd St., New York NY 10011; Sun Control Products, 431 Fourth Ave. S.E., Rochester MN 55904; Verosol USA, 224 RIDC Park West Dr., Pittsburgh PA 15275. **Insulating shades and shutters:** Appropriate Technology Corp., Box 975, Brattleboro VT 05301-0975; Boston Shutter & Door, Box 888, Island Mill, Keene NH 03431; Comfortex Corp., Box 728, Cohoes NY 12047; Jaksha Energy Systems, 2450 Rosswood N.E., Rio Rancho NM 87124. **Ventilating fans:** Vent-Axia, Box 2204, Woburn MA 01888; Weather Energy Systems, Box 459, West Wareham MA 02576. **Flooring:** American Olean Tile Co., 1000 Cannon Ave., Lansdale PA 19446; Dal-Tile Corp., Box 17130, Dallas TX 75217; Mid-State Tile, Box 1777-T, Lexington NC 27293; Summitville Tiles, Summitville OH 43962. **Phase-change material:** PSI Energy Systems, 1533-T Fenpark Dr., Fenton MO 63026

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Glazing

[Continued from page 81]

It also suggests how well you'll see out of your sunspace when the glazing is glass or the monolithic acrylic and polycarbonate sheets. But with the structured-sheet plastics and fiberglass-reinforced plastics (FRP) that's not the whole picture. They may have good visible transmission, but the light is diffuse—great for many plants and for privacy, but not if you want a view.

Glass vs. plastic

Plastic is much lighter than glass, and it can be bent on site to form curved sections. It is also much more impact resistant. GE Plastics says its Lexan polycarbonate sheets are 250 times stronger than glass. "If you have branches overhanging the sunspace, or vandalism is a problem, a glazing that resists breakage is worth considering," says Gray. "The structured-sheet plastics, especially the polycarbonates, are the most impact resistant," he adds.

Local building codes may have specific requirements for sloped or overhead glazing. If ordinary glass is used, a screen may have to be installed beneath to catch the shards if it should break. Codes generally allow laminated glass to be used without a screen, and some now permit tempered glass. Appropriate plastics are also permitted.

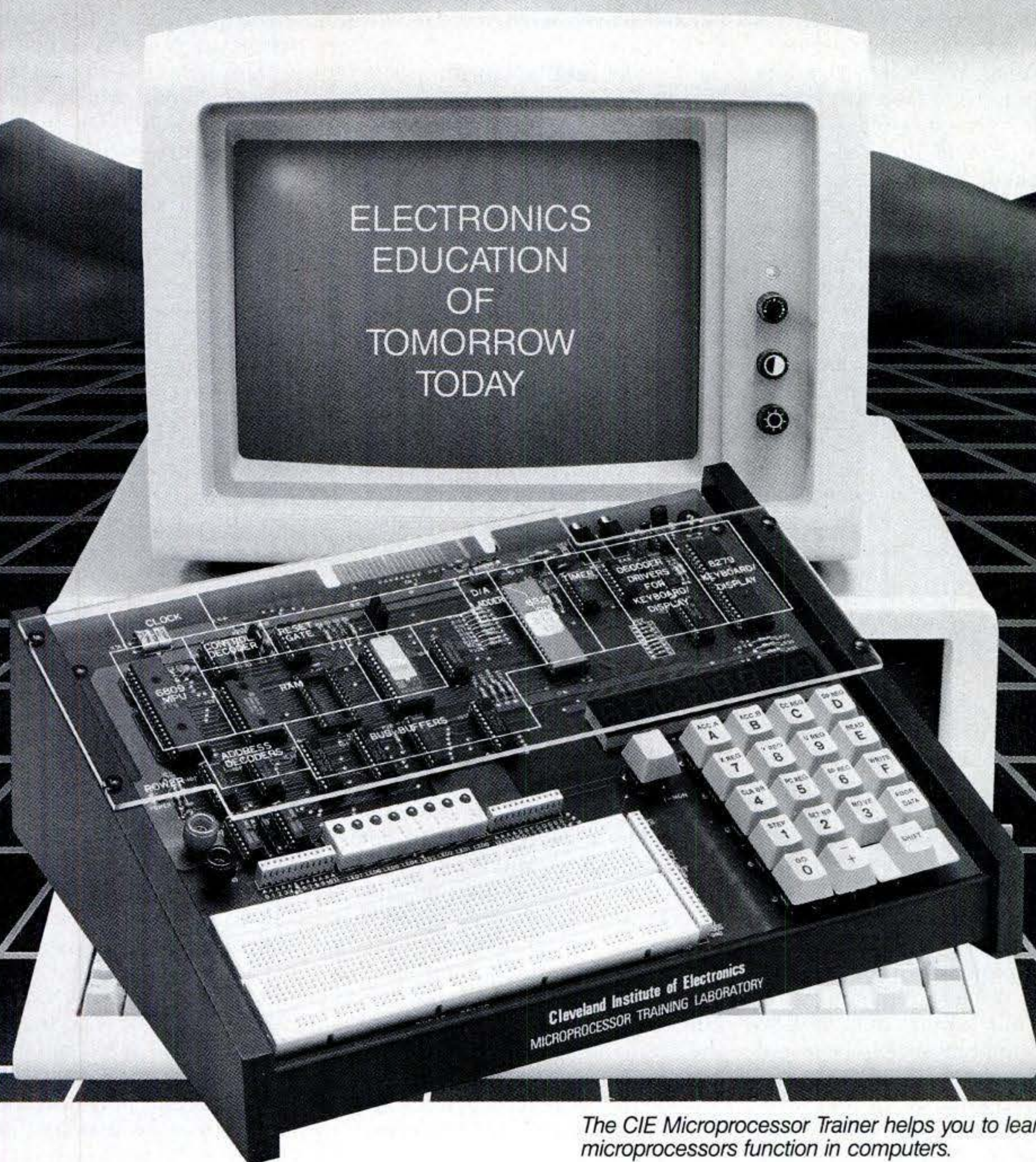
But plastic glazings scratch more readily than glass, they are flammable, some may yellow over time, and the monolithic sheets are flimsy, requiring closer spacing of the sunspace frame. The structured sheets don't provide a clear view. Plastics also have a high coefficient of thermal expansion, so seams are harder to seal. Special installation methods and materials must be used.

Whatever glazing you choose for your sunspace, you may find that thermal blinds and shading devices are necessary if you want it to be a comfortable living space—day and night, winter and summer. **P 5**

SOME MANUFACTURERS OF GLAZINGS MENTIONED:

The following companies make glazing and sell it to window and sunspace makers. They do not sell glazing to consumers. **Glass (including low-emissivity):** AFG Ind., Box 929, Kingsport TN 37662; Ford Glass Div., Box 43343, Detroit MI 48243; Guardian Ind., 43043 W. Nine Mile Rd., Northville MI 48167; Interpane Coatings, Box 26, Deerfield WI 53531; PPG Ind., Glass Group, One PPG Place, Pittsburgh PA 15272. **Heat Mirror low-e film:** Southwall Technologies, 1029 Corporation Way, Palo Alto CA 94303. **Acrylic and polycarbonate glazings:** Cyro Ind., 100 Valley Rd., Box 950, Mount Arlington NJ 07856; GE Plastics, Structured Products Dept., One Plastics Ave., Pittsfield MA 01201; Rohm & Haas Co., Independence Mall W., Philadelphia PA 19105. **FRP (fiberglass-reinforced plastic):** Filon Div., 12333 S. Van Ness Ave., Box 5006, Hawthorne CA 90250; Kalwall Corp., 1111 Candia Rd., Manchester NH 03103. **Laminated glass:** Monsanto Co., 800 N. Lindbergh Blvd., St. Louis MO 63167 (makes butyl film used in laminated glass). **Other sources:** National Greenhouse Manufacturers Assn., Box 567, Pana IL 62557; Andersen Corp., Foot N. Fifth Ave., Bayport MN 55003; Four Seasons Solar Products Corp., 5005 Veterans Memorial Hwy., Holbrook NY 11741

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APS-30

machine tools—presents problems, he notes. “We tried an irregular piece of tungsten carbide, but as yet we haven’t been able to get uniform coverage.”

There are also problems with adhesion of the films. Engineers at Sumitomo Electric have experimented with diamond-coated machine tools. “The coating worked well at first,” says Akira Okaya, a technical staff member at the company’s New York City office, “but after a while it would come off.”

General Electric claims to have solved some of these problems. “We’ve found proprietary ways to get relatively uniform coatings on irregular objects,” says Thomas Anthony, a staff scientist at GE’s corporate research and development center in Schenectady, N.Y. Drawl of Penn State says that one possible way to get uniform coatings is to hit the sample with multiple plasma sources from different angles.

Anthony also says that GE’s coating process produces surprisingly thick films—“thicker than a millimeter.” As a result, he says, it may soon be possible to deposit robust diamond coatings on a mandrel that would then be dissolved away, leaving behind a hard all-diamond nozzle, cutting tool, or other useful object, thus circumventing the adhesion problem.

Diamond chips

Further down the development track are diamond-based semiconductors. Because of diamond’s high thermal conductivity, it has great ability to shed heat. Thus semiconductor chips of diamond could conceivably be placed more closely together than their silicon-based counterparts, yet not overheat. This would allow for faster transport of electrons, thereby increasing operating speeds. Diamond is also radiation resistant, so it could be used in space, where radiation might destroy silicon or gallium arsenide devices.

But there are formidable obstacles on the road to practical devices. For one thing, semiconductors require a continuous single crystal of diamond, not the separate little crystals (polycrystalline films) that have been grown with most current techniques. Also, it’s not easy to penetrate hard diamond with dopants, the intentionally added impurities that make the material semiconducting. So dopants must be added during the deposition process. And conventional etching techniques used to create patterns on silicon wafers are useless with diamond. Finally, diamond films must be grown on a substrate that’s economical for large-scale production.

Progress is being made under the

ONR program. “The substrate is the key issue in getting single-crystal diamond,” says Robert F. Davis, professor of materials science and engineering at North Carolina State University in Raleigh, where attempts are being made to grow semiconductor-grade diamond. In particular, he says, its crystal structure must resemble that of natural diamond “so that the carbon atoms line up to form diamond all across it rather than in little spots.” Indeed, until a short time ago the only substrate upon which single-crystal diamond had been grown was costly natural diamond—an achievement announced several years ago by Sumitomo Electric. But recently investigators under Robert Markunas at the Research Triangle Institute in North Carolina succeeded in depositing single-crystal diamond on an inexpensive nickel alloy that has a structure closely resembling that of diamond.

“This is what is needed to make diamond technology economically viable,” explains Max N. Yoder, a program manager in the ONR’s electronics division, though he concedes other innovations are also required.

At the Massachusetts Institute of Technology’s Lincoln Laboratory in Lexington, Mass., where investigators are trying to make electronic devices from diamonds, Michael Geis, a research staffer, says he and his colleagues have developed a new etching technique specifically designed for diamond. “We use nitrogen dioxide. That’s the same gas that pollutes the atmosphere,” he says. “We spray it on the diamond surface and hit it with an ion beam. The nitrogen dioxide breaks up and reacts chemically with the surface to etch the patterns.”

A researcher and physics professor at the University of North Carolina in Chapel Hill, Wei-Koo Chu has come up with a way to get metal contacts to adhere to diamond. “We bombarded the surface with a beam of carbon ions,” he says. “Working like a sewing machine, this sort of stitches it on.”

Diamond discs

Diamonds are also being considered as protective coatings on a new generation of ultra-high-density magnetic data discs that store information in thin layers of mechanically and chemically vulnerable metal alloys. Diamond is attractive, says Barry Schechtman, manager of advanced recording technology at IBM’s Almaden, Calif., research center, not only because it is strong and hard, but because “the protective coatings will have to be very thin” to permit the recording head to fly over the disc with

a tiny clearance. Still, Schechtman admits that today’s high processing temperatures “would destroy the magnetic properties” of the computer discs.

For many new applications, getting process temperatures down is a key research goal. For example, a low-temperature process is needed for generating those protective coatings. One such technique: the so-called “ion-beam” method. In this process a diamond coating is produced by bombarding a substrate in the presence of hydrogen gas with carbon ions produced by a hot carbon cathode.

Diamond coatings can also be produced by sputtering, a technique in which ions are knocked off a solid carbon block by bombarding it with an electron beam. There’s one problem, however: Ion-beam methods usually produce not true diamond, but *diamondlike* coatings—films composed of carbon and hydrogen, not the pure carbon of diamond. Diamondlike coatings possess some of the mechanical, chemical, and electrical properties of true diamonds, but lack their tightly ordered crystal structure.

Costume jewelry?

“For many applications diamondlike films are more practical than diamond films,” says GE’s Anthony. “In fact, they have up to half the hardness of true diamond.” With the diamondlike films, he notes, “You can coat large areas and do it at low temperatures.”

But the low-temperature ion-beam method is advancing too. Penn State’s Messier says he is trying to adapt low-temperature ion-bombardment techniques to diamond production. “Right now you can only use ion bombardment to make diamondlike coatings; but we’re trying to use it to inch closer and closer to true diamond.”

Whatever the path of progress, specialists say the pace for diamond-film development will be gradual. “I think you’ll see quite a few products introduced over the next two to five years,” says David D. Hoover, a diamond-coating researcher with Air Products and Chemicals in Allentown, Pa. These, he says, will be primarily in optical coatings and non-semiconductor electronic applications, such as heat sinks. As for workable semiconductor devices, Penn State’s Roy sees them being a decade away.

How much of an impact will diamond films make? “What I see is diamonds filling niches where people demand hardness or special thermal or electronic properties,” says Messier. But those could be some mighty big niches, he hints. “There’s just an awful lot of interest out there,” Messier says, pointing to his stack of mail. 

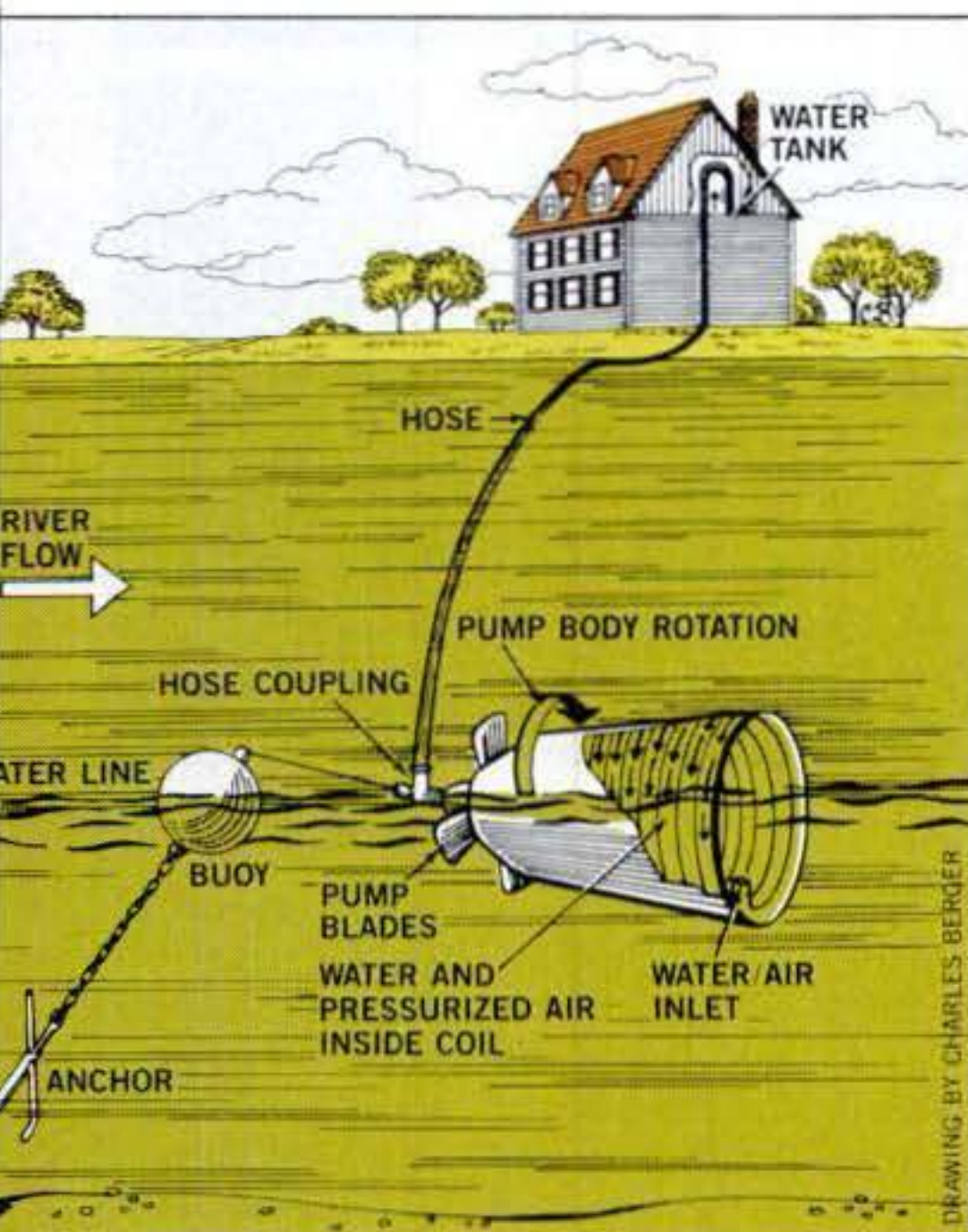
Floating pump

If you need a dependable water supply for irrigation or household use but live in a remote area where fuel and electricity are scarce, this new pump may be the answer. It's powered solely by running water. Anchored in a stream or river, the pump sends a continuous flow of water to an elevated tank. Because of the simplicity of its design, the Sling pump may be especially useful in developing countries. It can operate anywhere there's a current, even in shallow water only a foot deep.

Tethered to a stake or buoy (see drawing), the pump is partially submerged. Inside the body is a spiral coil of pipe. As the pump rotates, an inlet hole in the pipe takes in alternate gulps of water and air. The pockets of air are compressed as the water column advances toward the narrow end of the tapered coil, and the pressurized air forces the trapped water out through a hose, which is attached to the pump by a rotating coupling.

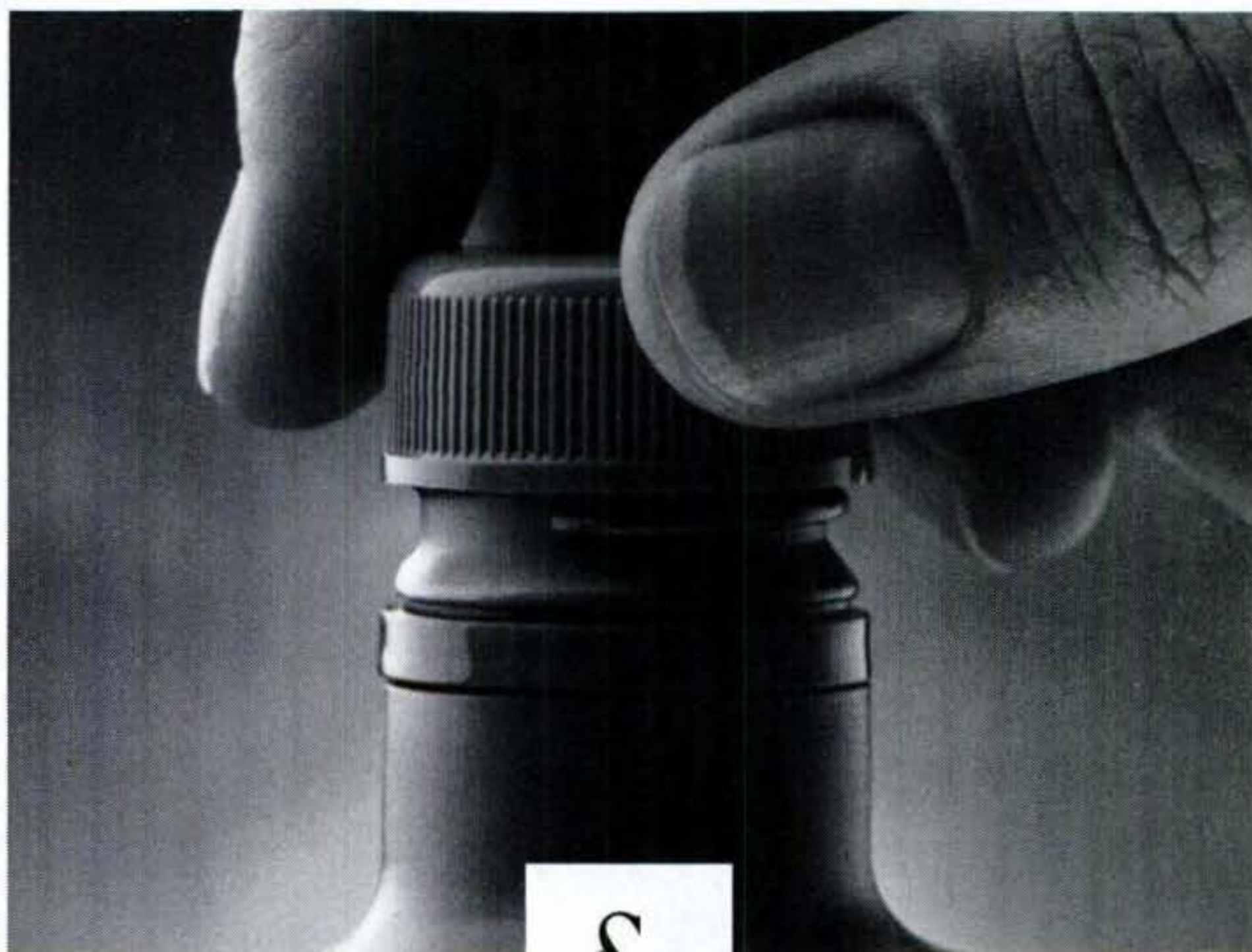
The smallest model, which weighs 15 pounds, pumps water up to a head of 26 feet. At a water-flow speed of two feet per second, it delivers 830 gallons a day to a water tank. Larger models have pumping heights of 36 and 49 feet.

Made in Sweden, the Sling pump is undergoing long-term tests in Somalia and Tanzania. It has no valves or other moving parts, so it's virtually maintenance-free. JTM Produkt AB, Box 51, 980 21 Jukkasjarvi, Sweden.—David Scott

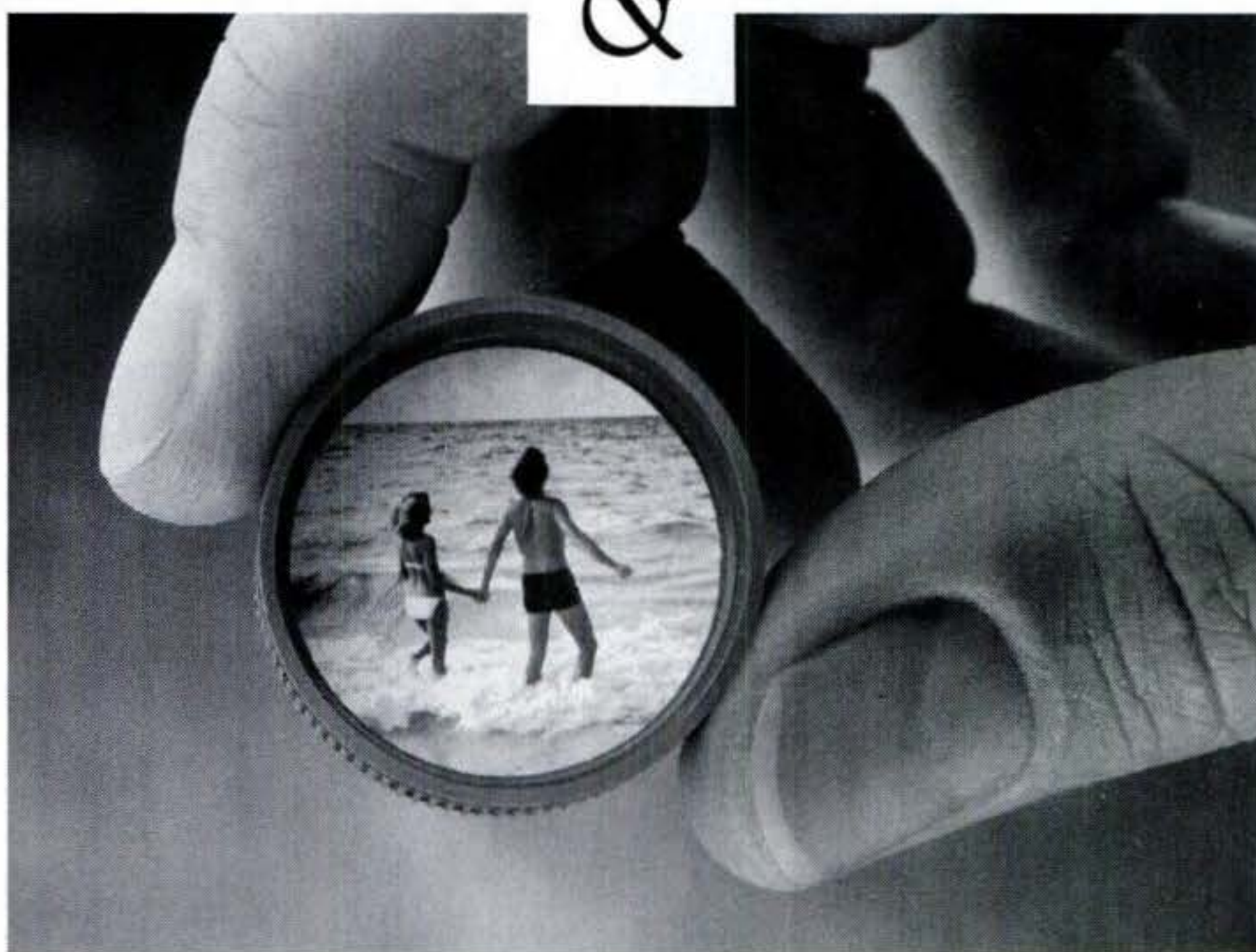


Current strikes blades, spinning the pump's body and its water/air inlet. Water is forced through hose to tank.

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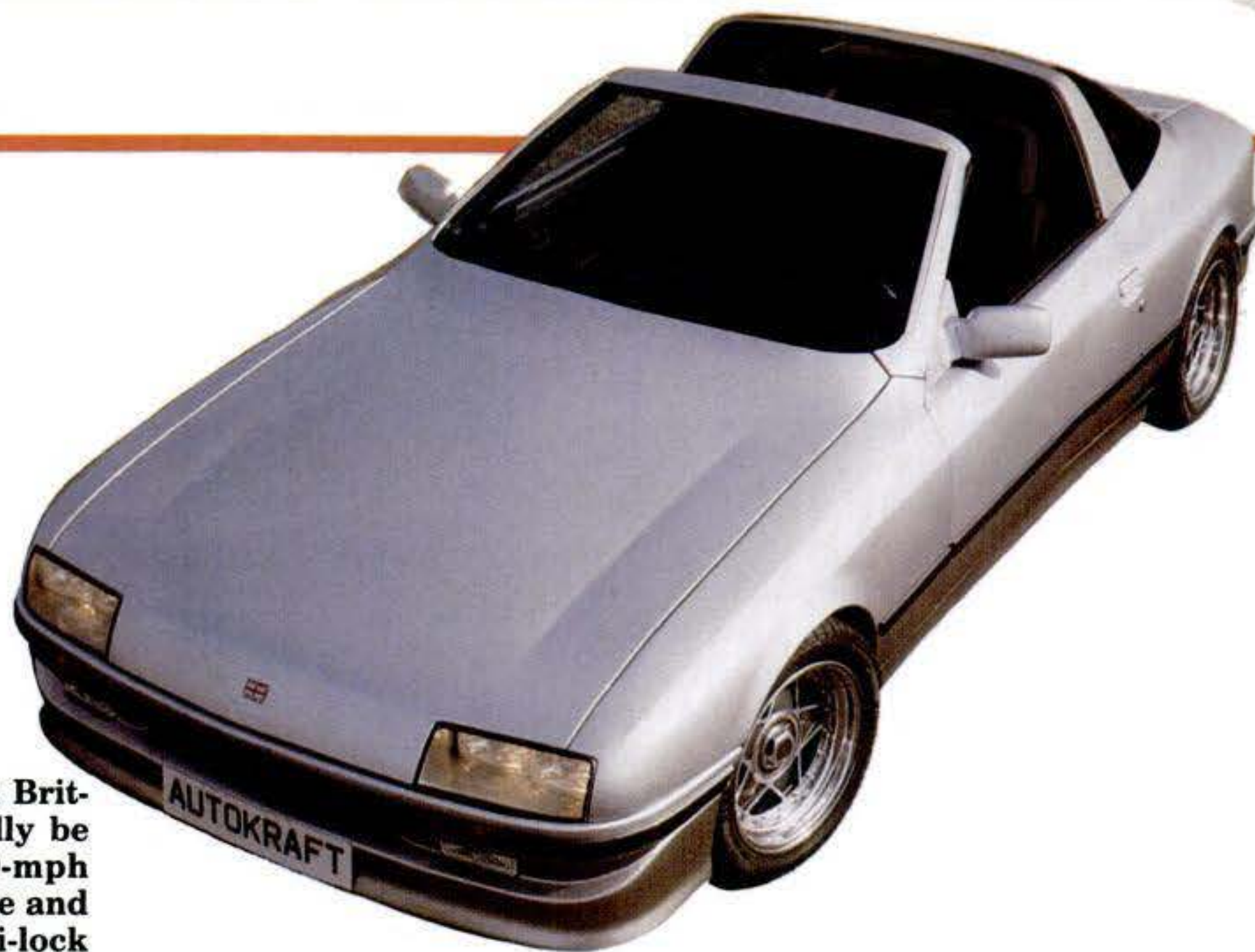
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BY DAWN STOVER

What's New



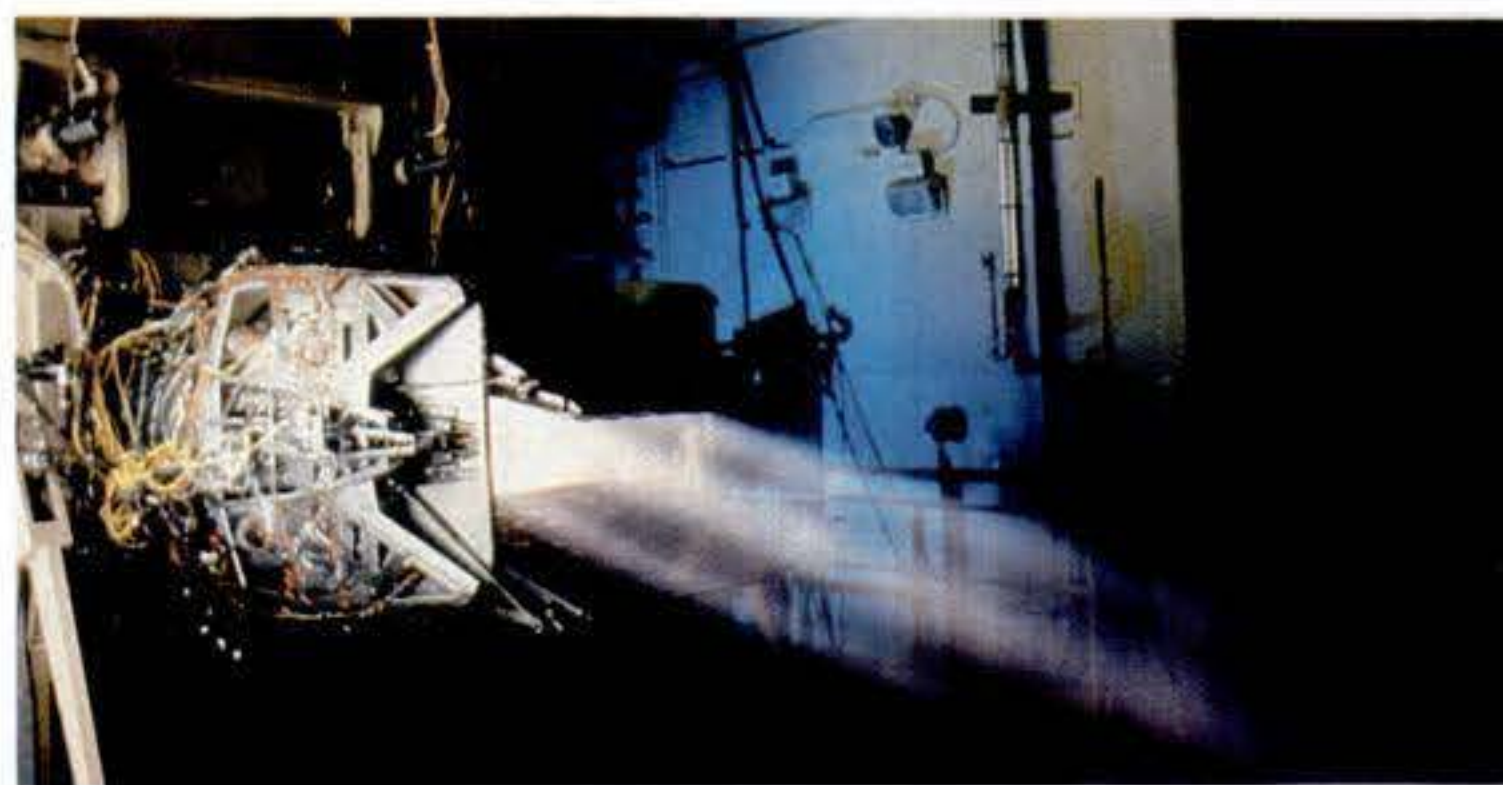
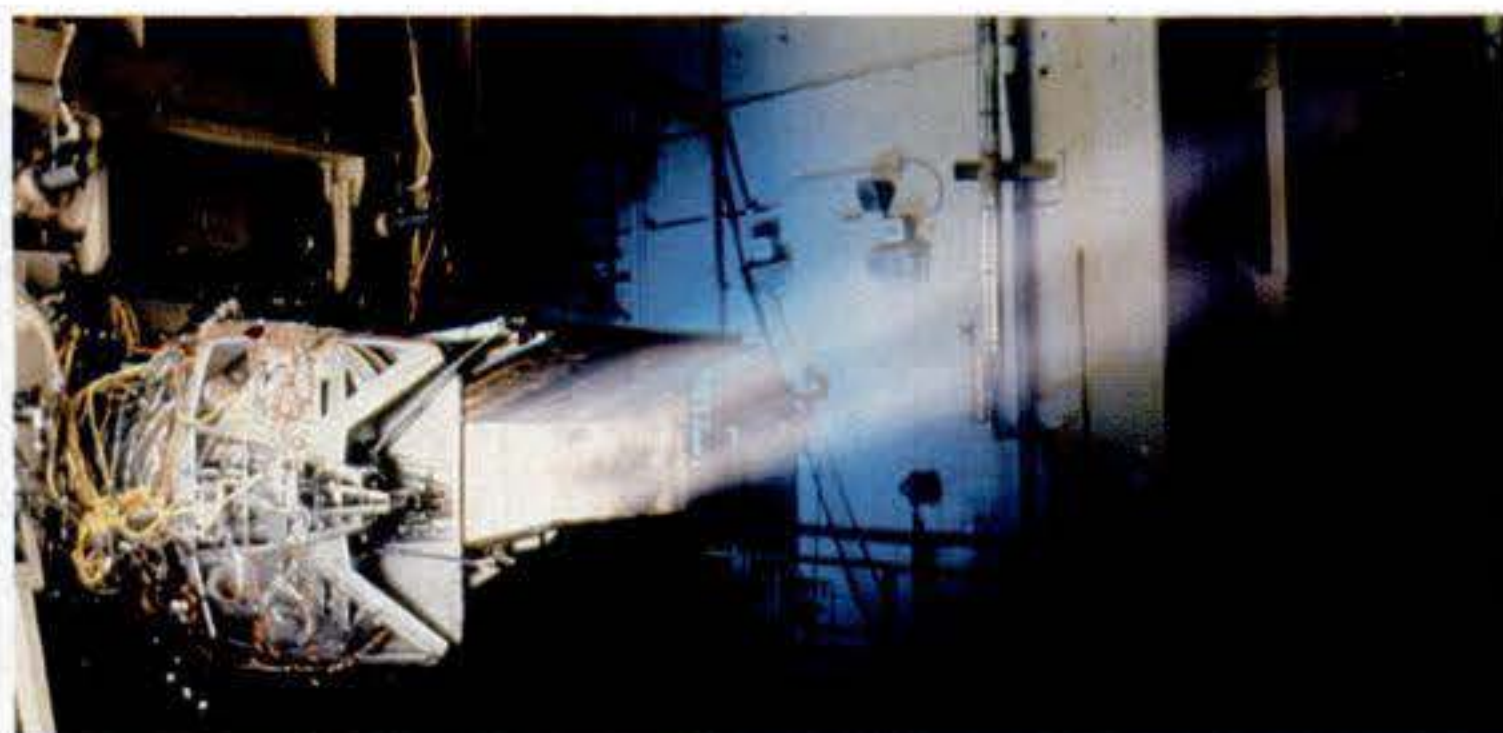
Targa-type two-seater ►

Ford of Europe's takeover of AC Cars, a small British company, means the AC Ace may eventually be exported to the United States. The 4WD 140-mph sports car has a 2.9-liter V6. The Ace's drive line and transmission are based on Ford designs. Anti-lock brakes are standard on the 46-in.-high car.



◀ Built-in light

This under-cabinet GE Spacemaker radio has a light with two settings: It sheds bright light on your counter or serves as a night light. The \$83 AM/FM stereo radio can also turn on an appliance at a preset time.



◀ Inside-out building

Huge concrete columns support 12 open-deck galleries in the new Lloyd's of London offices. Identical columns support the outer walls, which feature glass-paneled elevators and 50 miles of stainless-steel piping for heating, air conditioning, and other services.

2-D nozzle ▲

Unlike conventional round nozzles, this engine-exhaust nozzle can change the direction of the engine's thrust or reverse it. The Air Force will test the 2-D nozzle on a STOL demonstrator aircraft.



Piston-powered plane ▲

Powered by two Nissan six-cylinder turbocharged engines, the Pond Racer will approach 600 mph, says designer Burt Rutan of Scaled Composites. Named after Bob Pond of Advance Machine Co., it's made almost entirely of graphite—a material never before used in a production aircraft.

Jet stream adds maneuverability ▼

Twin jets give this 450-passenger Swedish ferry a top speed of about 28 mph with low vibration and noise levels. Nozzle valves redirect the flow to give stepless speed control, from full speed ahead to full speed reverse. MarineJet Power Systems, Box 130, 742 00 Osthhammer, Sweden.



What's New TOOLS

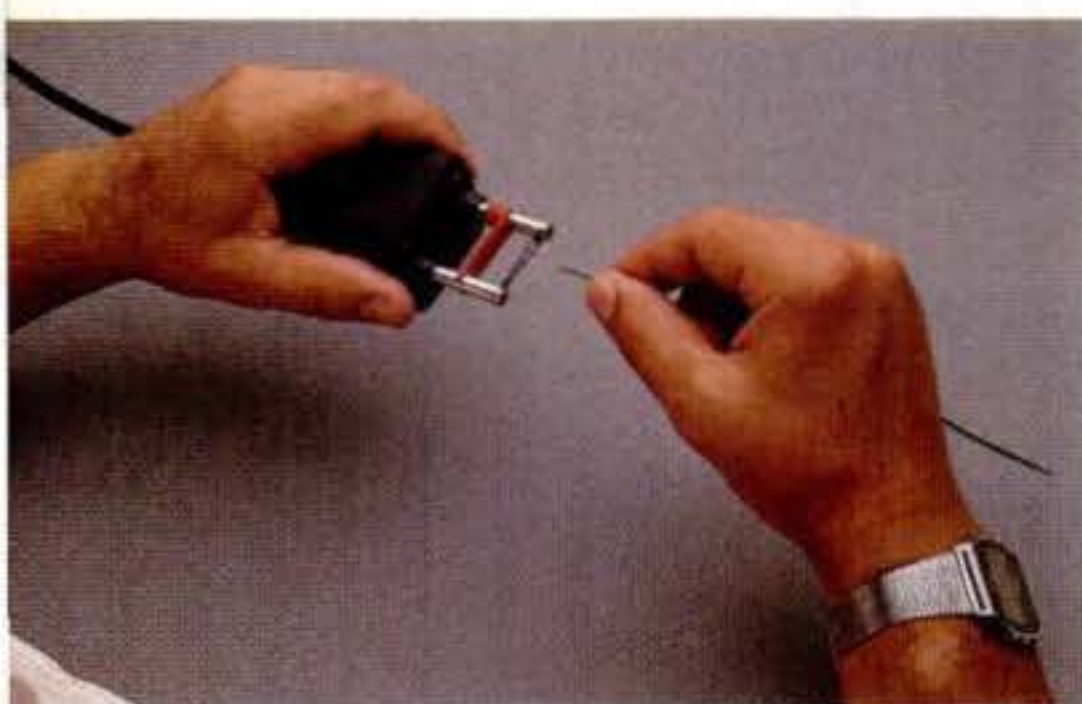
Four-footed ladder ►

If the adrenaline rush you get when working from a shaky ladder is your idea of a jolly Saturday-afternoon adventure, these clip-on stabilizing legs are not for you. They keep a ladder stable on unlevel ground, minimize twisting, and keep it from slipping backward when it's propped at a shallow angle, says the maker. The die-cast aluminum legs slide down to their respective support positions and grip the rails with two fiberglass lugs; the climber's weight locks them on. Stabilad Ltd., Enterprise House, Keymer Rd., Burgess Hill, West Sussex RH15 0AN, England.



SawTaurus? ▲

Inside the slinky gumdrop body of this 7¼-in. saw revs a 13-amp ball- and needle-bearing motor. The shoe pivots in front to adjust the depth of cut. And the clever saw shuts off when brushes need replacing. Robert Bosch Power Tool Corp., Box 2217, New Bern, N.C. 28560; \$179.



Hot stripper's act ▲

Apply a little heat, and you can get the job done better, says Patco. The Thermal Wire Stripper uses an extremely thin, hot element to melt the insulation around wire, producing a clean cut with rounded edges. It eliminates nicks and damaged conductors, says the maker. The \$46 tool is from Patco Service, 2515 Glencoe Rd., Baltimore, Md. 21234.



◀ Piggy-vac

The VACaROO's 1.1-hp motor does double duty: For big jobs you clamp it to the 8-gal. tank (left); for minding minor messes you can switch it to the 2-gal. tank (below). The wet-dry vacuum is \$130. Genie Co., Box 6352, Akron, Ohio 44312.



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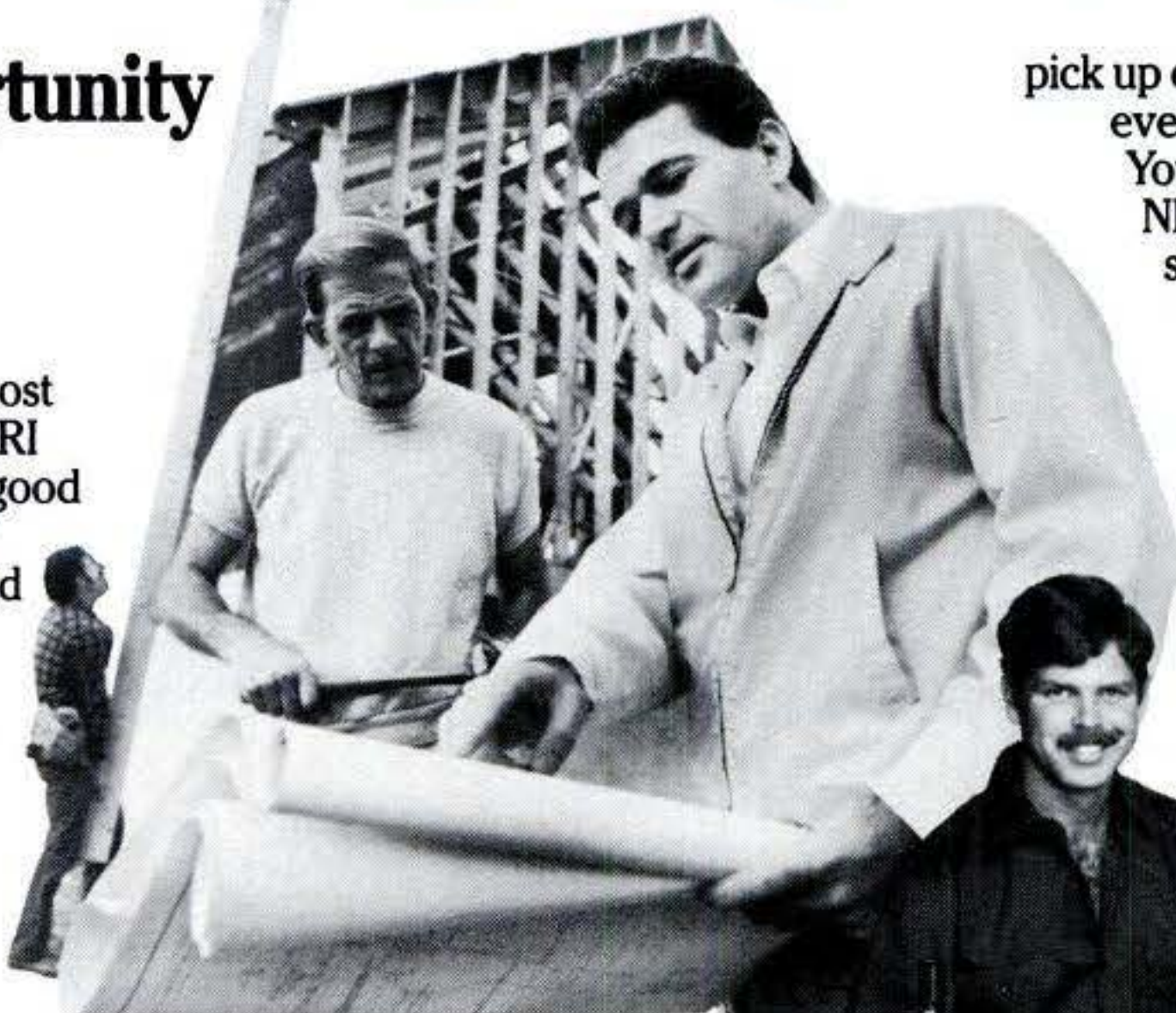
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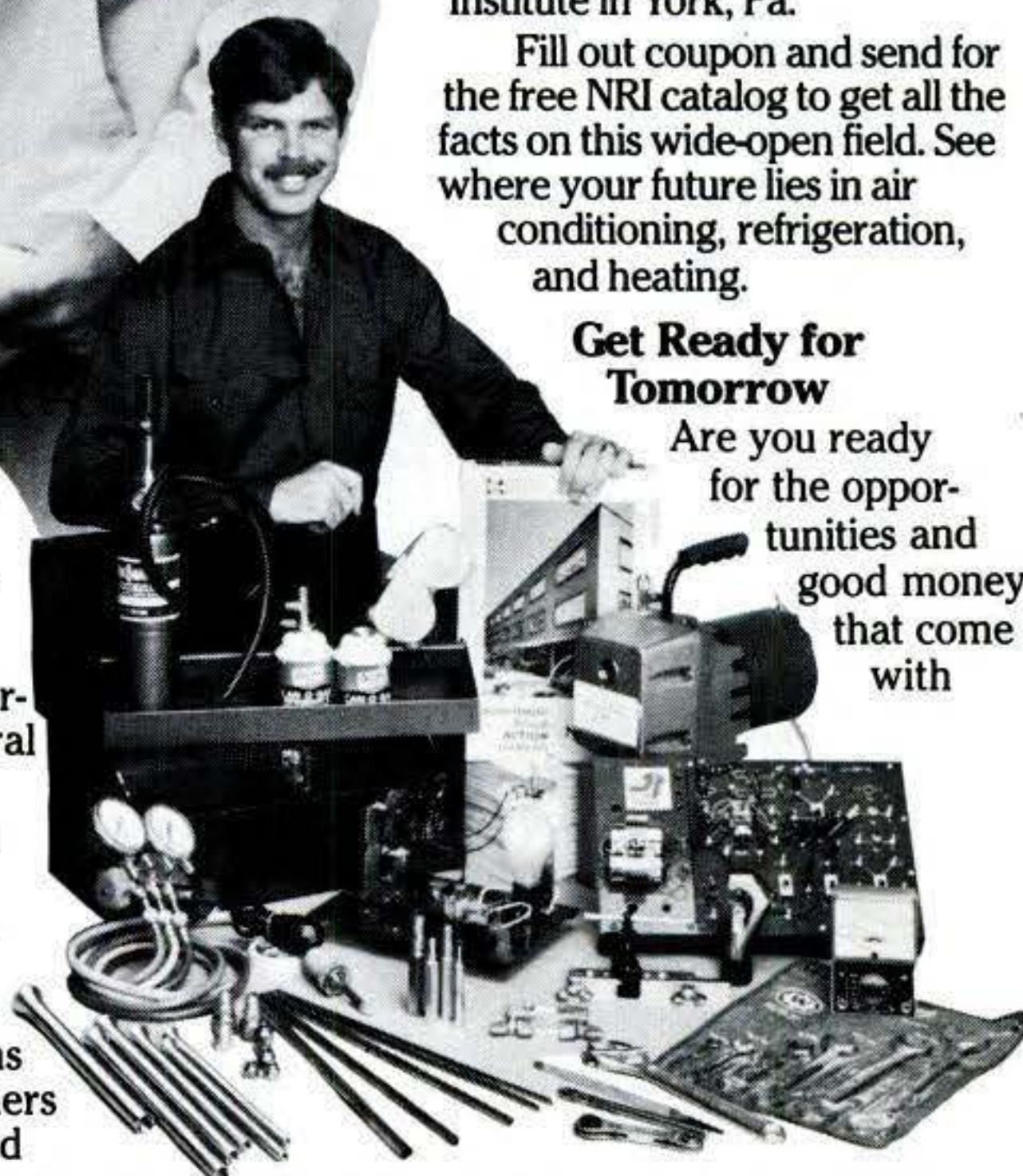
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Line-topping lawn tractor ▲

Yamaha's top-of-the-line YT3600 lawn tractor uses a 12-hp overhead-valve engine to power a hydrostatic transmission through an automotive-type drive shaft. A single lever controls infinitely variable ground speeds. With 38-in. mower and electric power takeoff, the tractor costs \$2,849.



Nimble mower ▲

With its zero-turning-radius, dual-lever steering, dual hydrostatic drive, 11-hp engine, and compact 35-in.-wide cutting deck set out front, the Model 411 riding mower is designed for easy mowing and flush trimming around trees, plantings, and walls, says The Grasshopper Co. (Box 637, Moundridge, Kan. 67107). \$3,495.

Cordless blower ►

Now you can blow debris off decks, sidewalks, and driveways without the mess of gasoline or the tangle of an electrical cord. The \$50 Sweepstick weighs 3½ lbs. for one-handed operation, yet produces a 50-mph air-stream, says Black & Decker.

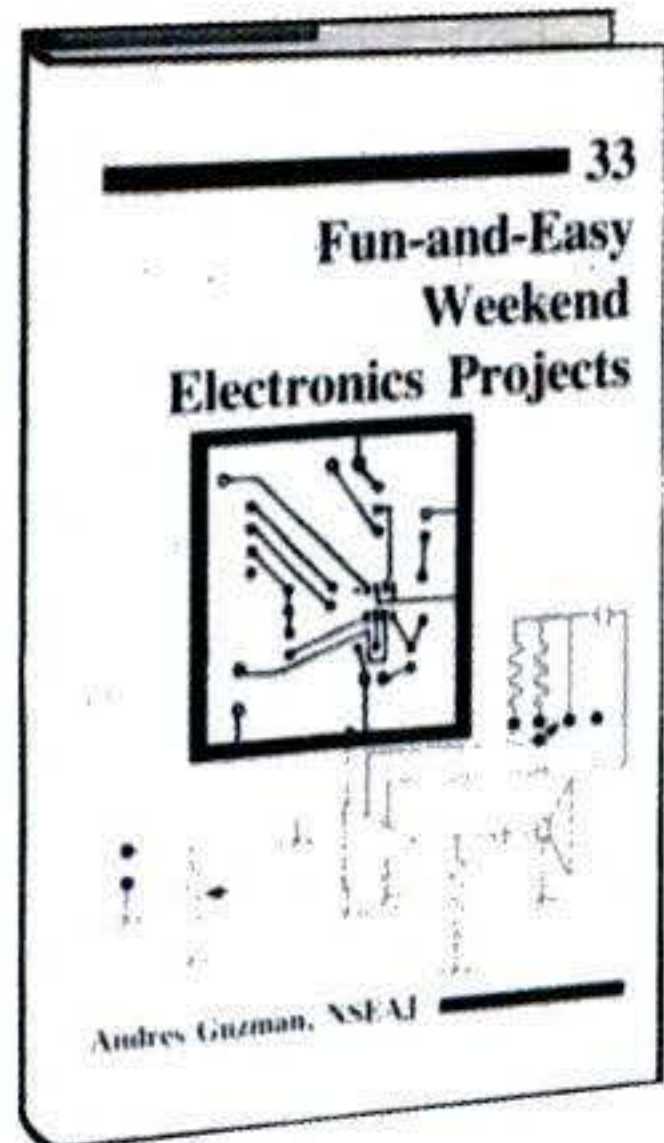
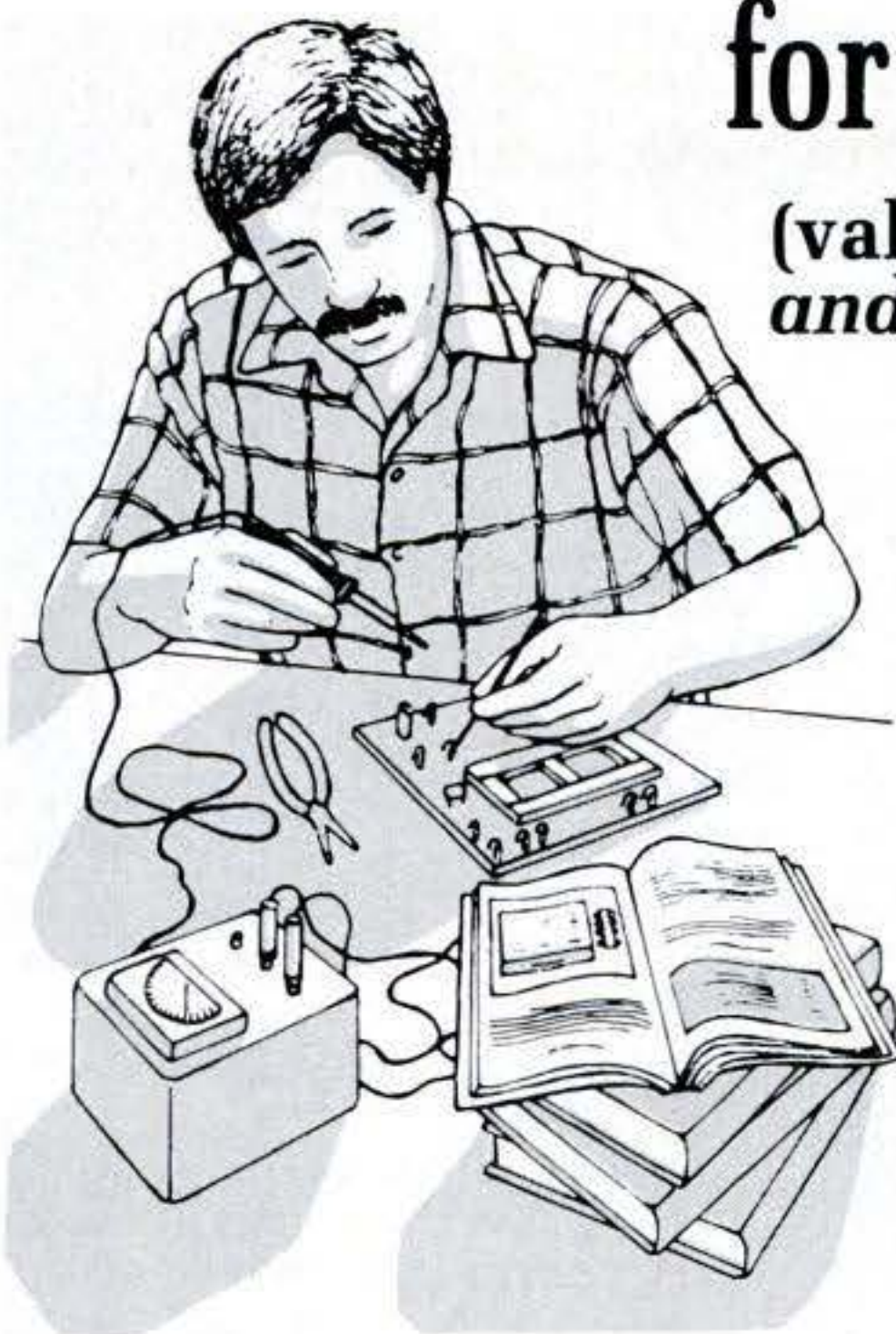


Mid-engine tiller ▲

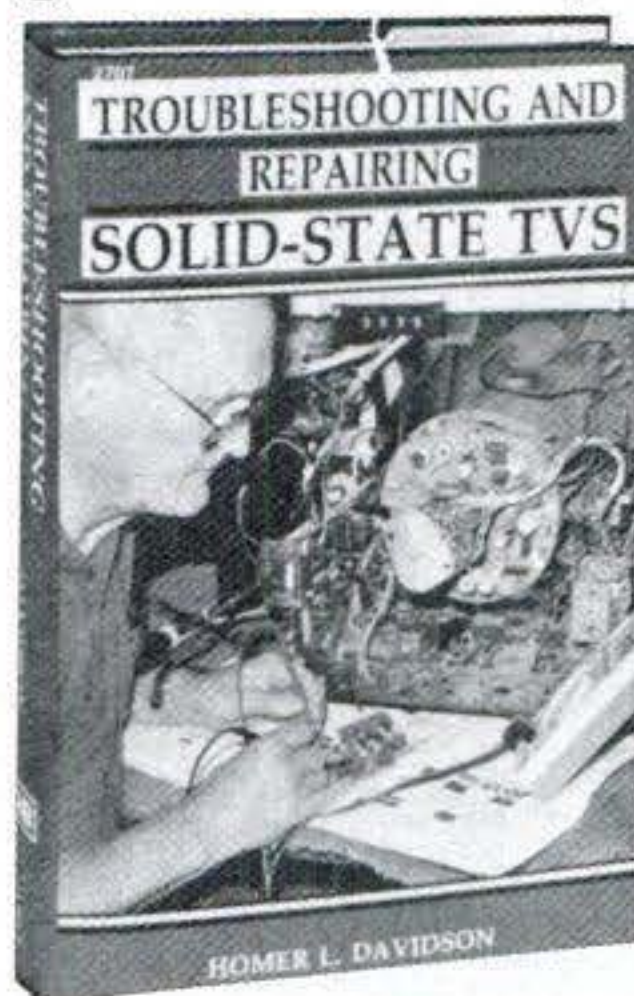
Mounting the 31-cc 2-cycle engine high off the ground improves the balance of its mini-cultivator and keeps the engine away from damaging dirt and dust, says Inertia Dynamics Corp. (7125 W. Galveston, Chandler, Ariz. 85226). Price: \$149.

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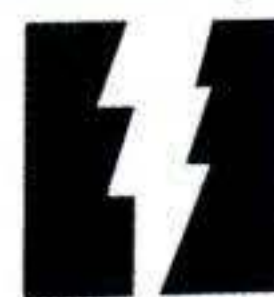
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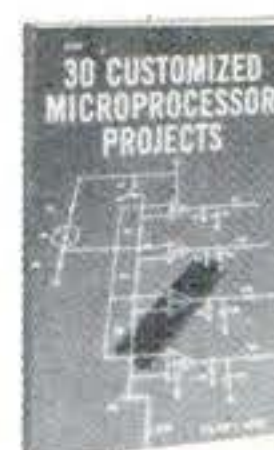
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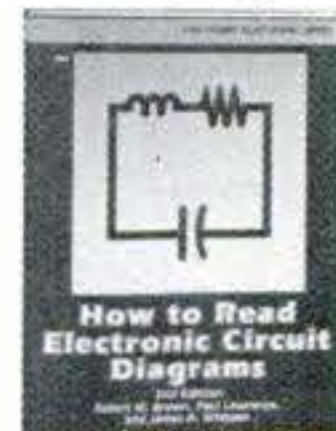
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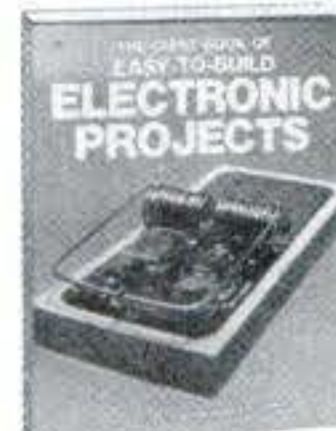
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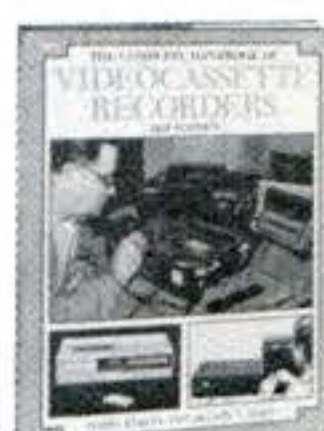
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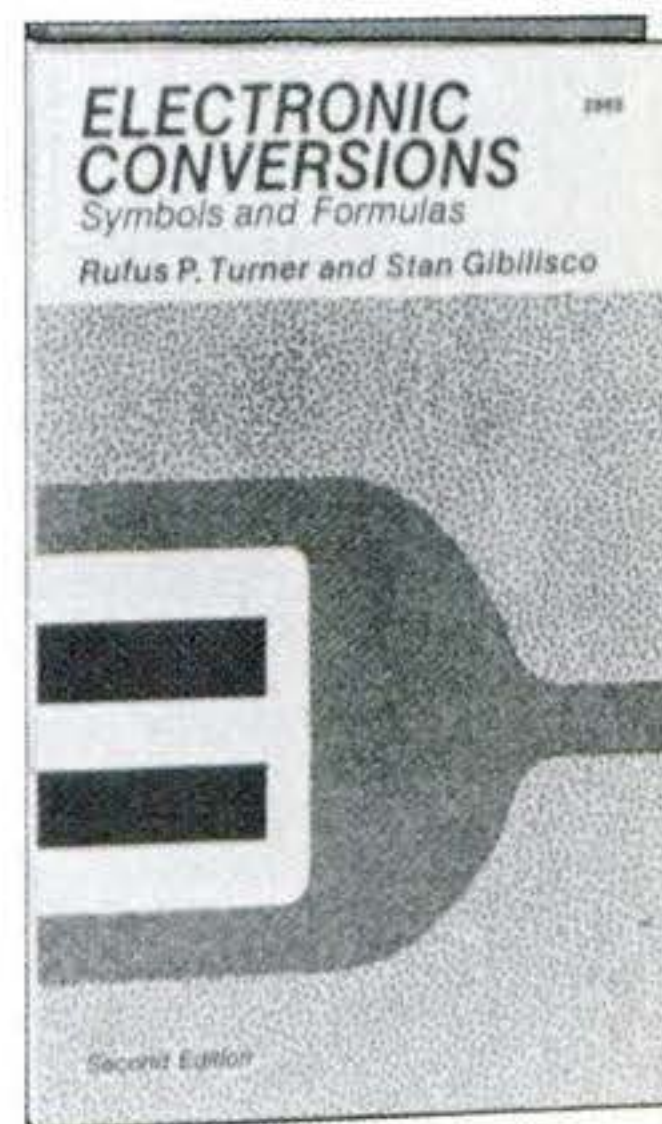
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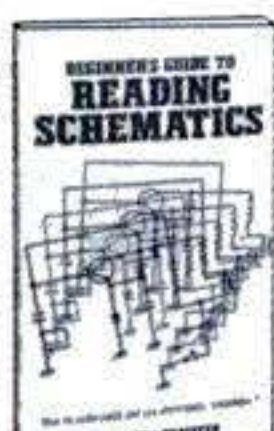
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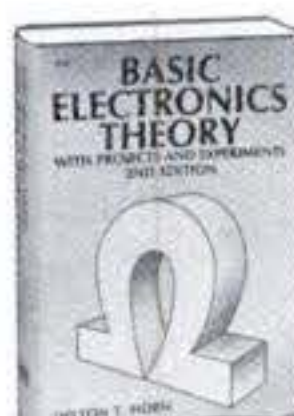
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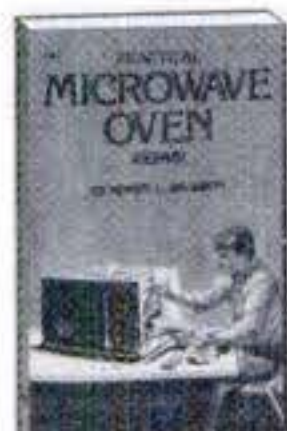
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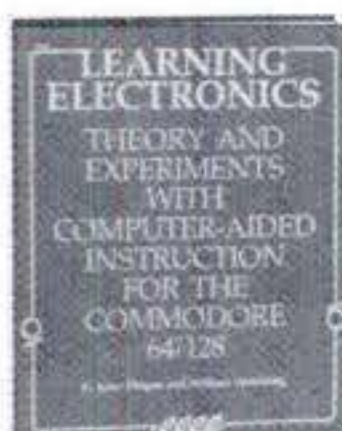
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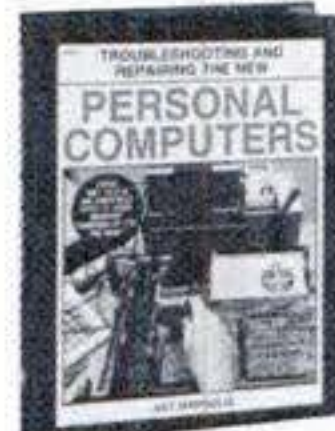
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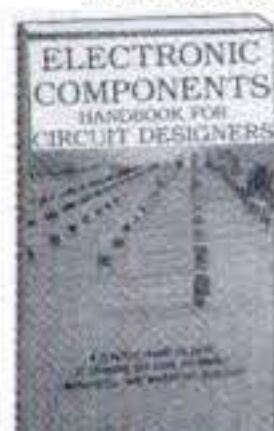
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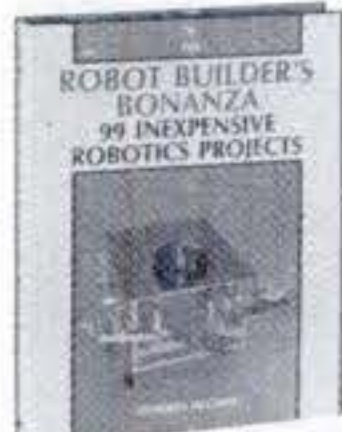
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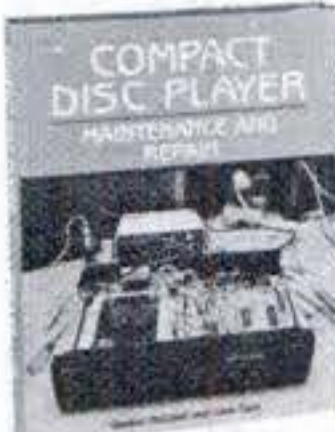
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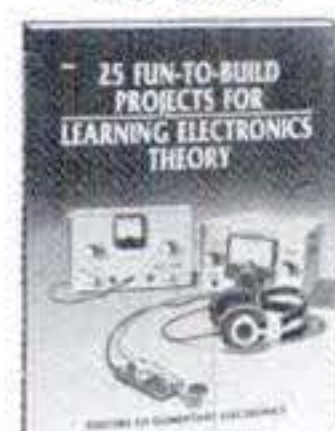
2800 \$23.95



2790 \$18.95



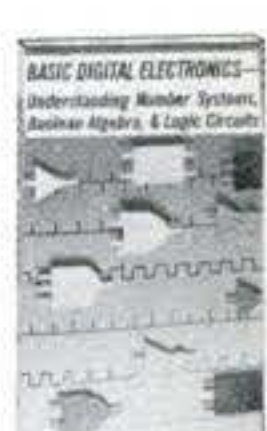
2735P \$13.95



2839P \$7.95



1199P \$18.95



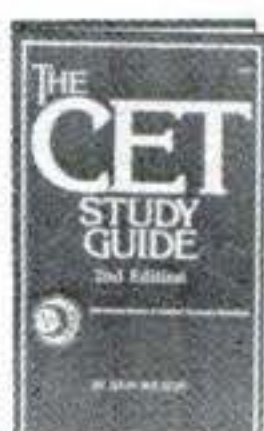
728P \$11.95



2912 \$23.95



1367P \$17.95



2941 \$21.95



1421P \$16.50

What's New HOME IMPROVEMENT

Handsome hood ►

Abbaka range hoods are formed from a metal plate, then fusion-welded and polished to remove any evidence of a seam. The wall-mount and island models have 27-in.-wide hoods and come in 36-, 42-, and 48-in. lengths. Abbaka, 435 23rd St., San Francisco, Calif. 94107. The price range: \$2,000–\$3,200.



Paddle stairs ►

These space-saving stairs have paddle-shaped treads that alternately reverse for left- and right-foot steps. The cutaway treads can be safely pitched steeper than conventional stairs, claims Elite Econo-loft Ltd. (S. Lanes Industrial Estate, Lancashire WN4 8DY, England).



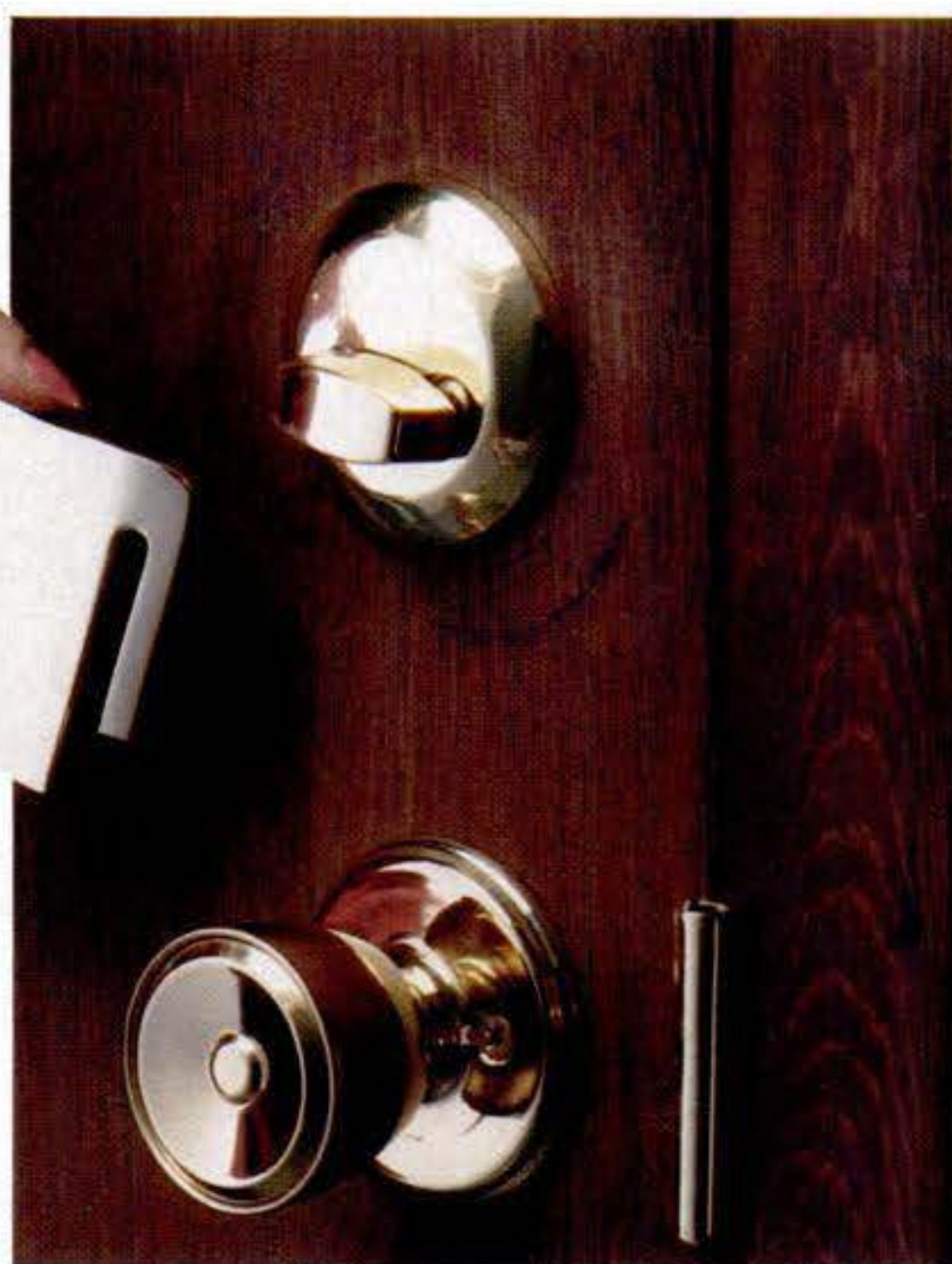
◀ In-between sheen

Is gloss polyurethane too shiny for you, and satin too dull? Varathane Semi-Gloss Liquid Plastic dries to a medium sheen that mimics the look of hand-rubbed furniture finish, says Flecto Co. (1000 45th St., Oakland, Calif. 94608). One quart is \$10.50.



No-key lock ►

Add security to your door without worrying about another key. Half of the Armour Keyless Security Lock replaces the current striker and half hooks over the doorknob, slotting into the new striker to secure the door. Global Enterprise, 461 Deborah Dr., Utica, N.Y. 13502; \$10.



Rough-texture stainer ▲

Rough-sawn wood, commonly used for fences and outdoor structures, soaks up lots of stain. So does the synthetic lamb's wool in the Model 3742 staining pad, which makes the \$6.50 pad good for staining such lumber, says Padco Inc. (2220 Elm St. S.E., Minneapolis, Minn. 55414).

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JOHN COUGAR MELLENCAMP The Lonesome Jubilee 3 4 4 2 0 [MERCURY] CD	PAVAROTTI Volare 2 5 1 0 2 [LONDON] CD	TAYLOR DAYNE Tell It To My Heart 2 4 7 5 9 [ARISTA] CD	DUTOIT Holst, The Planets 1 5 4 4 8 [London Digital] CD	Crosby, Stills, Nash & Young Greatest Hits (So Far) 3 0 2 3 0 [ATLANTIC] CD	BRUCE HORNSBY Scenes From The Southside 8 0 1 8 7 [RCA] CD
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Parton, Ronstadt, Harris Trio 1 4 8 0 4 [WARNER BROS.] CD	MR. MISTER Go On 4 4 1 2 7 [RCA] CD	ANDRE PREVIN Rimsky-Korsakov, Scheherazade 1 5 4 1 5 [PHILIPS] CD	THE BEST OF NAT "KING" COLE 1 4 4 3 2 [CAPITOL] CD	DWIGHT YOAKAM Hillbilly Deluxe 6 4 1 4 6 [REPRISE] CD	THE BEACH BOYS Endless Summer 2 3 5 5 9 [CAPITOL] CD
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What's New CARS

Clever key fob ►

Hands full? This key fob will lock and unlock your car and turn on and off the alarm system, according to the system's manufacturer, Ital Audi Ltd. (K&K House, Colonial Way, Watford, Herts WD2 4PT, England). The alarm's ultrasonic scanner also monitors the interior for intruders.



Oil mailer ►

Mail in a sample of your car's oil, and get a computerized analysis that looks for 21 metals, dust, coolant, unburned fuel, soot, and carbon contamination. The \$10 kit includes specimen vial, mailer, tubes and syringe, and written lab results. Detect Auto Labs, 122 E. 42nd St., New York, N.Y. 10168.



Mechanics' back saver ▲

Made of square tubing and checkboard-plate steel and padded with vinyl and carpet matting, the Mech-Aid workstand adjusts to five positions to help you avoid fatigue when bending over your car for long periods, says Freisen Enterprises (Box 356, Virgil, Ontario, Canada L0S 1T0). Cost: \$195.



Portable polisher ▲

This auto polisher plugs into the cigarette lighter and comes with washing, waxing, and polishing tools. It operates at 730 rpm and has a 16-ft. extension cord. The Marty's Gift Co., 314 W. 53rd St., New York, N.Y. 10019. Cost: \$16.



Hazard markers

In an emergency these compact hazard cones can be quickly pulled out of the trunk and erected. Called Quickcones, the pyramid-shaped warning reflectors have stable 2.2-lb. bases that can stand up to wind and road draft, says APH Road Safety Ltd. (Unit 7 Dunlop Rd., Hunt End, Redditch, Worcestershire B97 5XP England).

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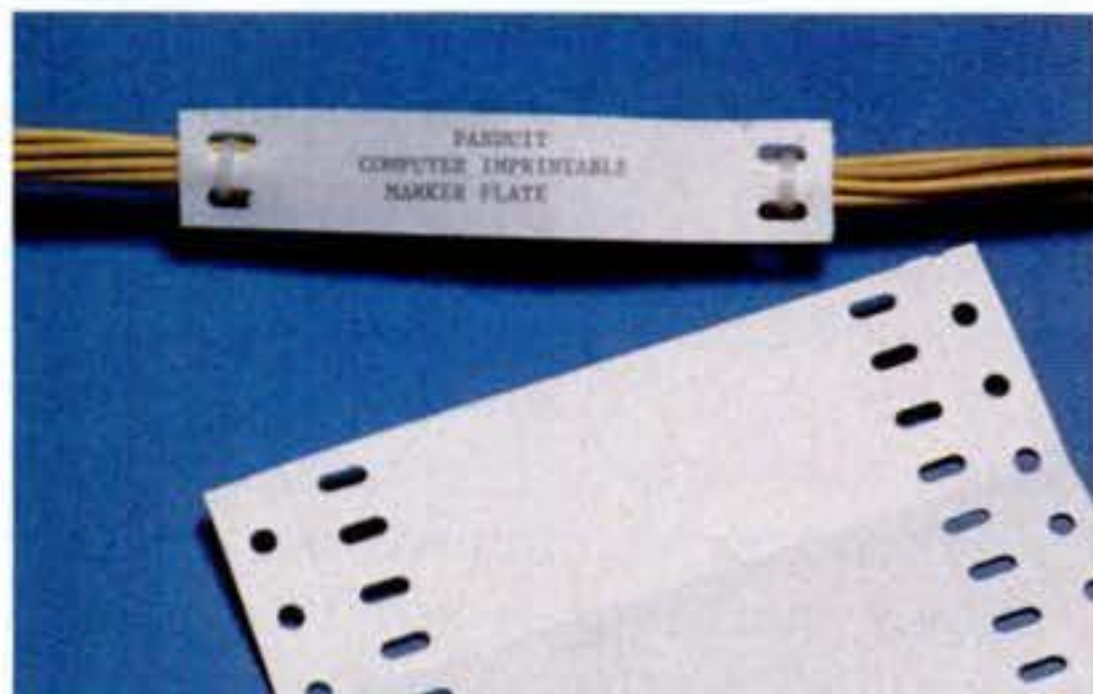
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What's New ELECTRONICS



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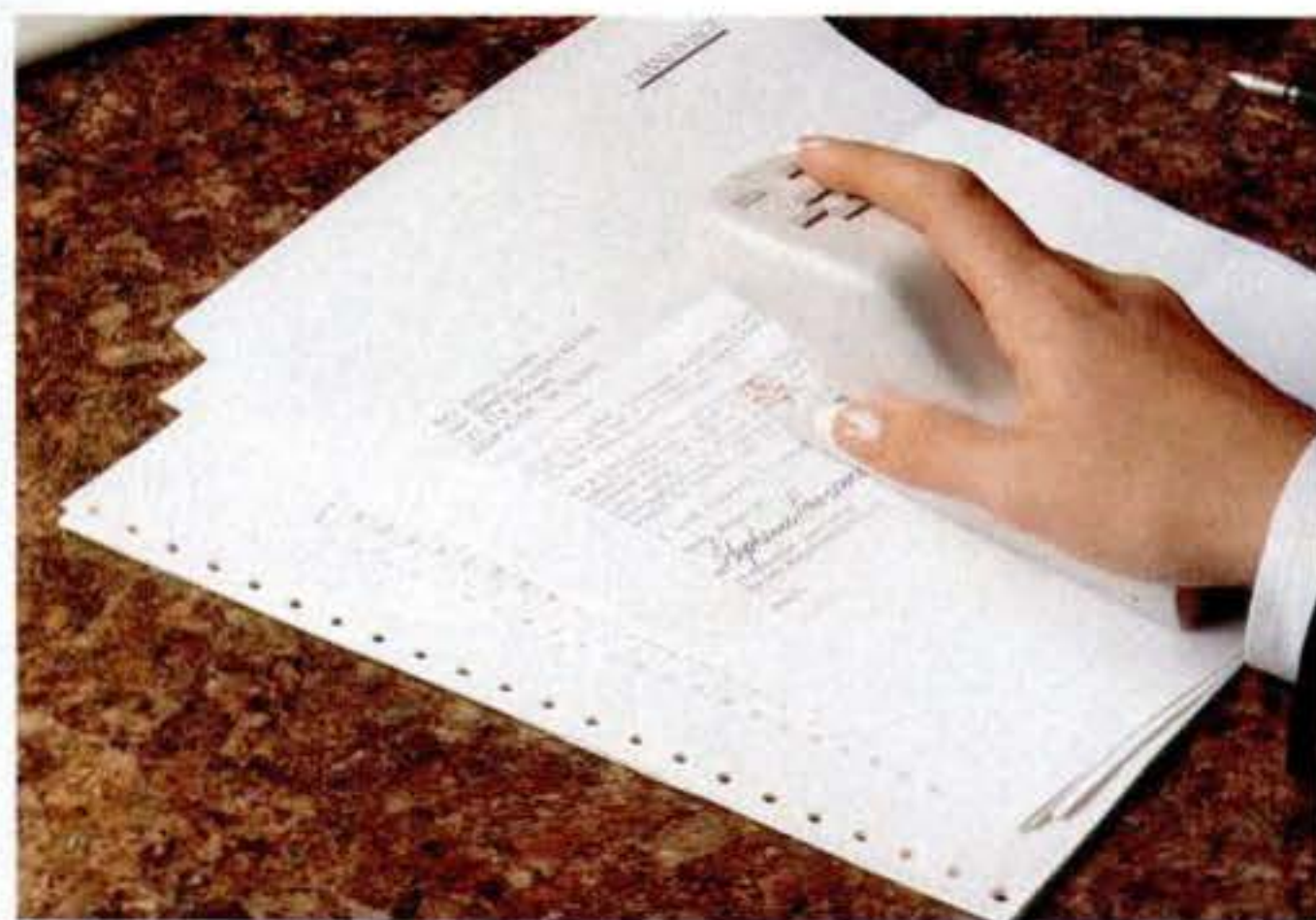
Wire markers ▲

Which wire is which? Mark hi-fi and computer cables for future reference with Panduit's semi-rigid cable labels. They can be printed on any tractor-feed printer. Available from Panduit Corp. (Electrical Group, 17301 Ridgeland Ave., Tinley Park, Ill. 60477).



Remote and more ▲

The \$600 B203 Revox Timer Controller lets you control the company's stereo components automatically via infrared remote control or by commands from your PC-compatible computer. Available from Studer Revox America, 1425 Elm Hill Pike, Nashville, Tenn. 37210.



Speedy reader ▲

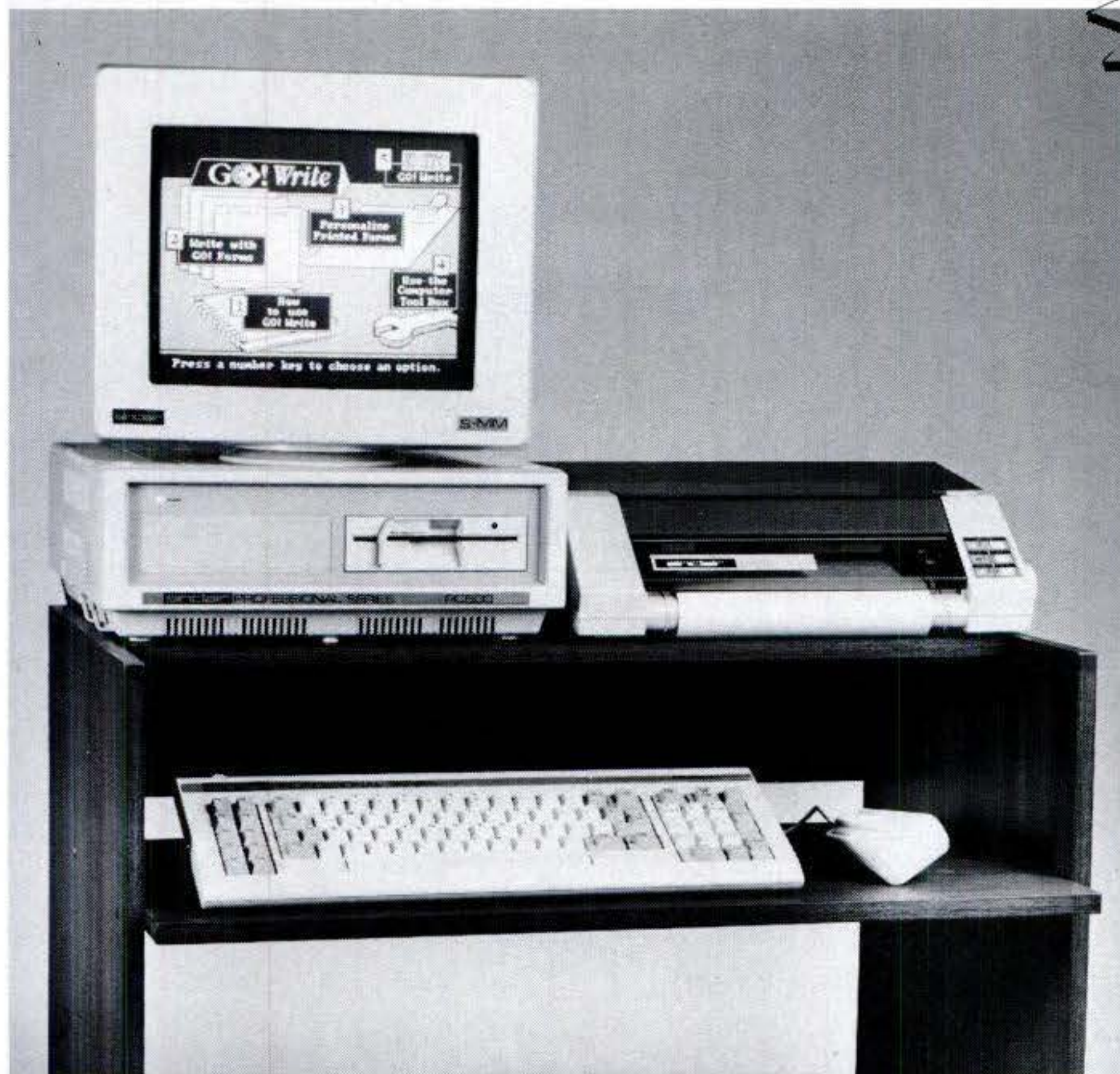
Sweep the TransImage 1000 optical character reader across lines of text, and it reads the characters into your computer for word processing. Made by TransImage Corp. (910 Benicia Ave., Sunnyvale, Calif. 94086), the \$2,950 device reads up to 40 characters per second.

◀ Ticking away

Happy birthday! According to the Fluxion clock you're exactly 1,102,139,852. The display shows your life in seconds. For clock watchers, it's \$495 from Fluxion Clock (5549 N. Lakewood Ave., Chicago, Ill. 60640).

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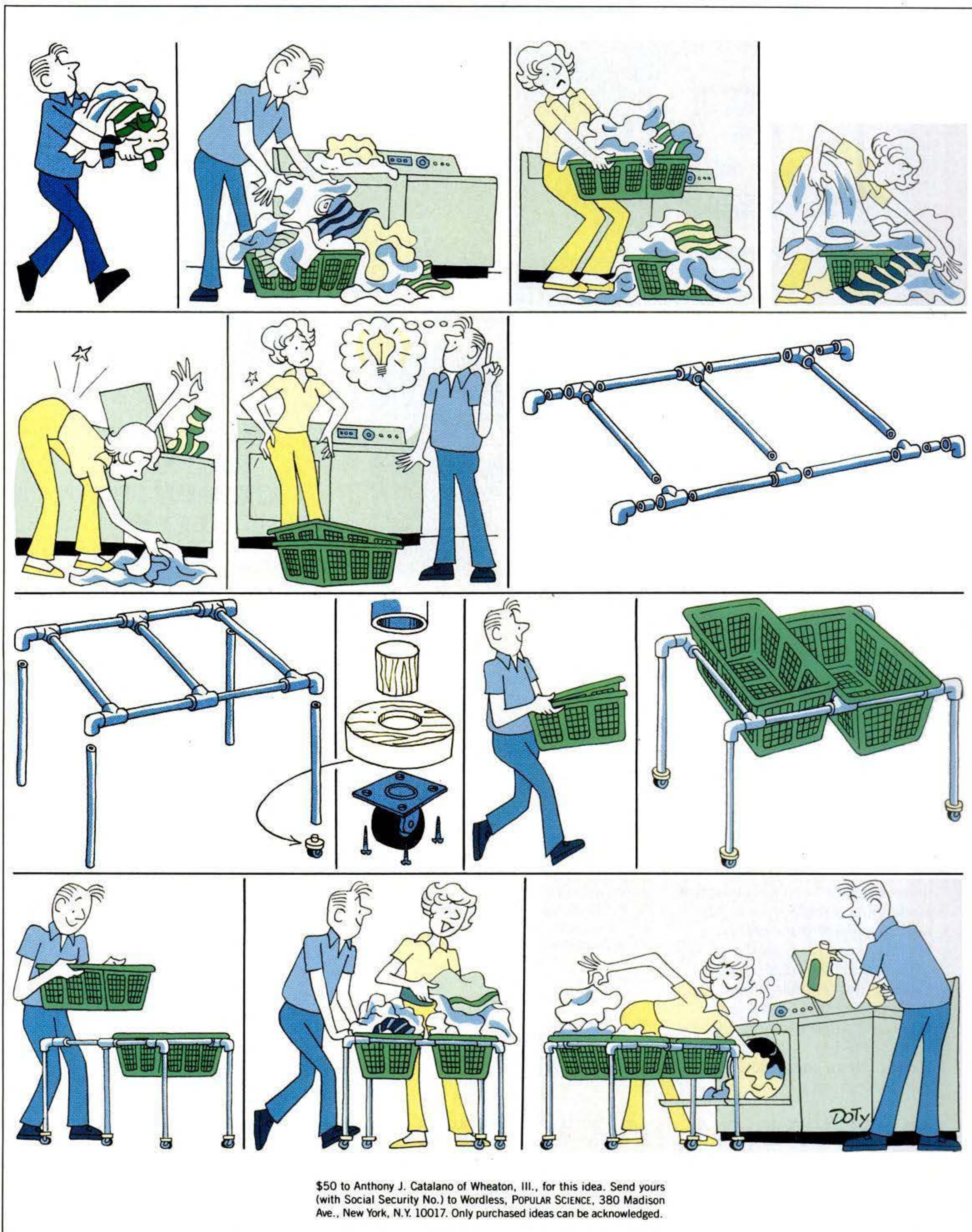
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Discriminating alarm

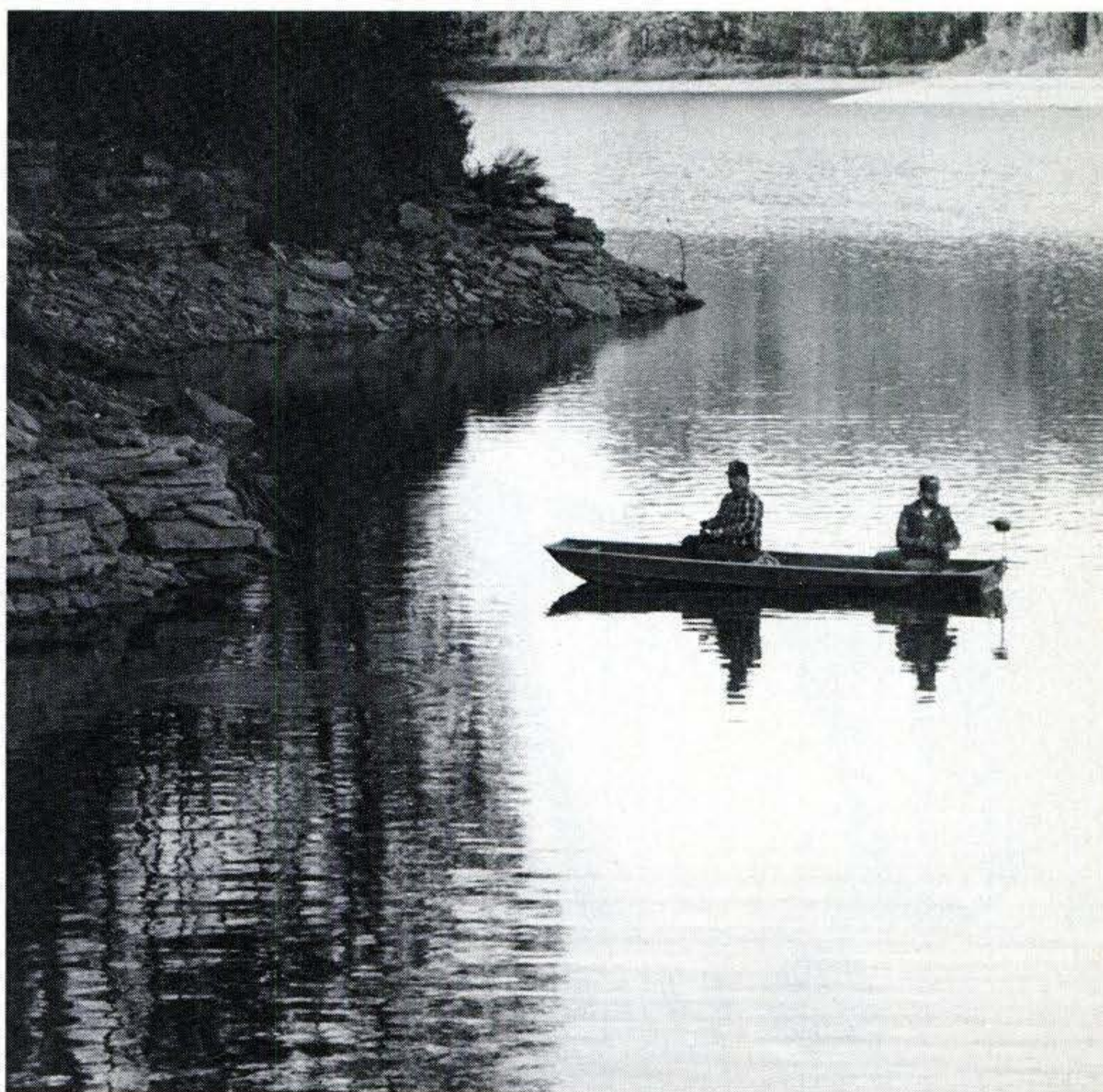
According to the National Safety Council, most of the estimated 900 deaths caused by accidental exposure to toxic gases in the U.S. last year were caused by carbon monoxide, a poisonous gas that's tasteless, odorless, and colorless. Because we cannot detect the presence of carbon monoxide, or CO, without help, and exposure to concentrations as low as 1,000 parts per million can cause death, a CO alarm can be an important addition to any house, especially one equipped with an electrically controlled furnace. The toxic gas, which is produced by the incomplete combustion of fuels, can escape into a house through tiny holes in the walls of the furnace's heat exchanger and harm residents.

Since their emergence a few years ago, CO alarms have been plagued by reliability problems—most having to do with false alarms triggered either by harmless transient exposures to carbon monoxide or by other gases. Up to now, the choice has been between putting up with the false-alarm nuisance or disconnecting the device entirely.

Recently, Quantum Group Inc. of San Diego introduced a CO sensor that it claims eliminates most of these problems. Unlike devices that only detect a dangerous concentration of carbon monoxide, the Quantum CO*Star measures carbon monoxide concentration and then calculates the *dosage over time*. This method not only prevents false alarms by allowing the device to tolerate occasional, though normal, elevated CO levels, says Quantum president and chairman Mark K. Goldstein, it also warns of acute high-level and chronic low-level exposures by calculating dosage over the preceding eight hours.

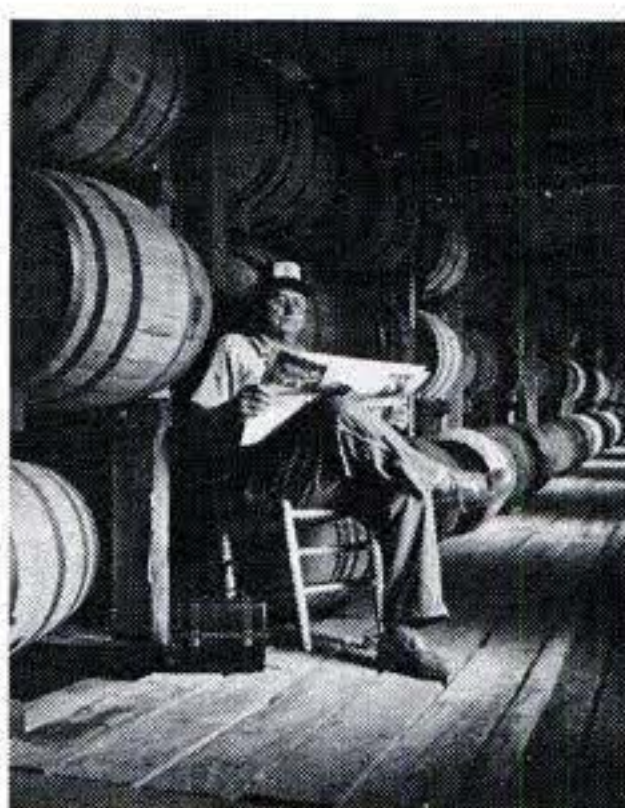
"There is some possibility of the CO*Star being set off by other gases," says Terry Anderson, vice president of Quantum, "but it has a software program that compares the signature of a detected gas to that of carbon monoxide recorded in its memory." Other gases are thus ignored, he says.

CO*Star (\$159) is available with ventilation and furnace controller units. The latter shuts down the furnace at dangerous CO levels; the former, meant for use in businesses where large amounts of CO are released, controls fans to vent harmful air. Quantum Group Inc., 11211 Sorrento Valley Rd., San Diego, Calif. 92121.—*Eduardo R. C. Capulong*



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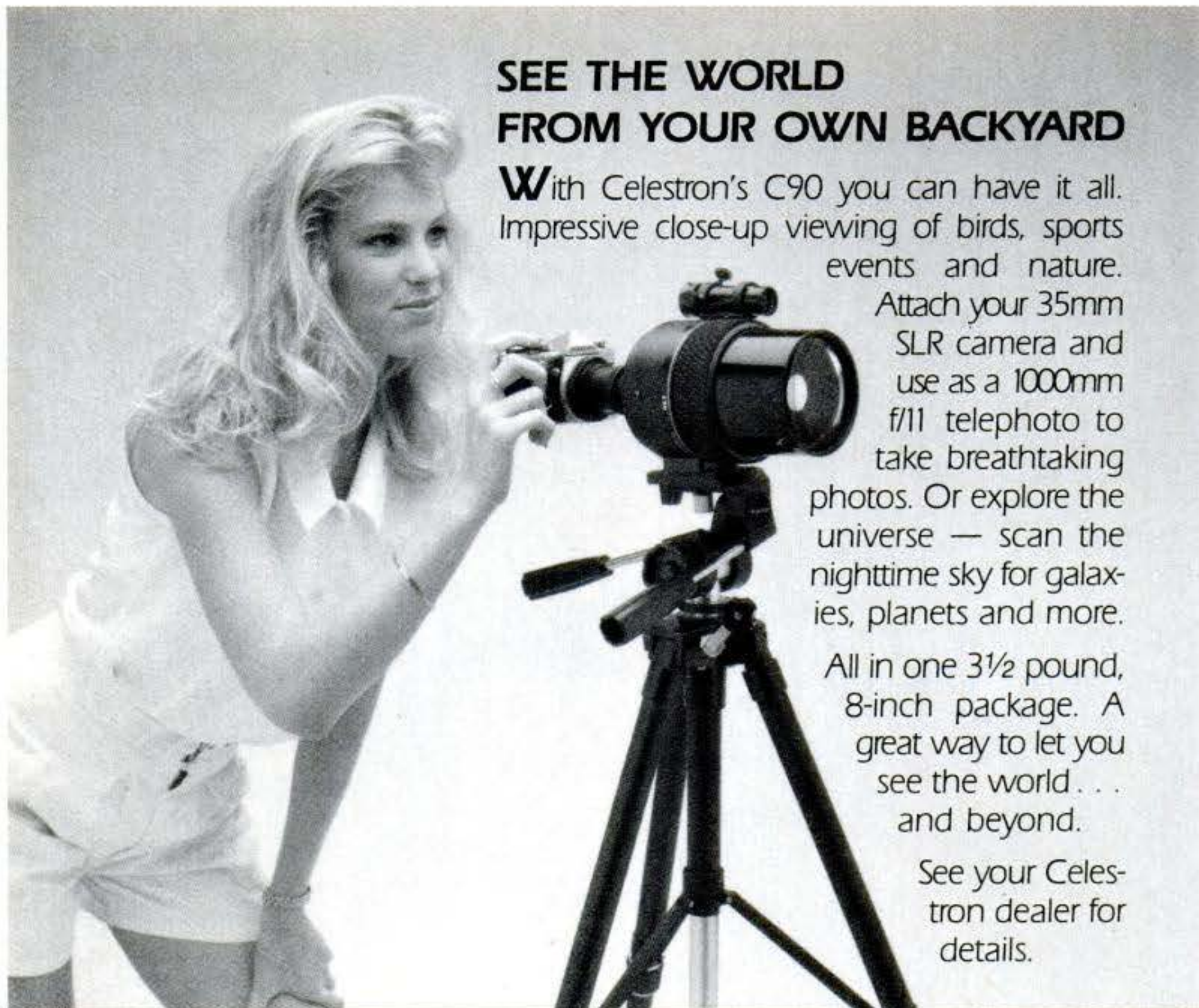
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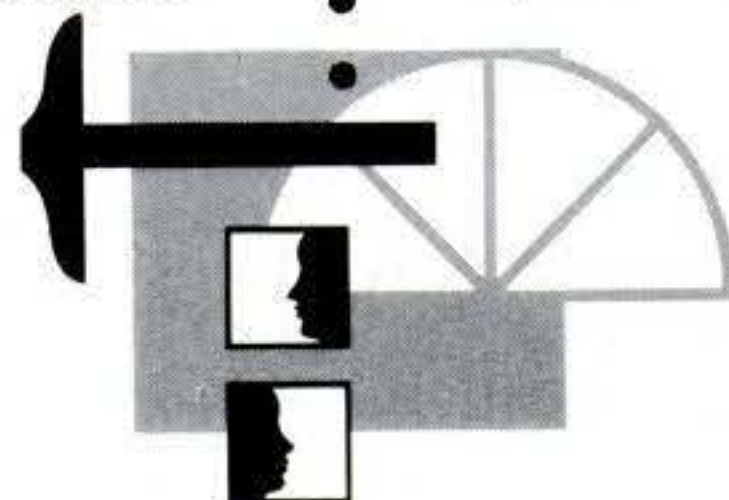
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Tandem-wing transport

[Continued from page 53]

solution was to use two wings connected by pods. Then the gear and engine become bending loads rather than twisting loads." As Rutan put it, "In effect, we're bending two wings instead of twisting one."

Dougherty continued: "Burt then set the forward wing at an angle of attack that makes it stall before the rear wing, so the plane is stall-limited; and he lengthened the pod behind the engine to reduce drag."

Fast flaps

Somewhat contrary to expectations, the extra set of wings and flaps doesn't improve the AT³'s short-field takeoff and landing characteristics, Rutan noted. That comes largely from his innovative use of large fast-acting flaps on the trailing edges of the wings. Maximum lift is needed for a short-field takeoff. When the AT³ begins its takeoff roll the flaps are extended aft. That reduces drag as the plane builds speed. Then just before liftoff, about 57 mph for a typical short field, the flaps rotate rapidly downward. Dropping the flaps gives the AT³ the sudden lift that sends it bounding skyward.

Rutan's designs are as much intuition and inspiration as hard engineering. He works to cut costs. "We're still doing lofts [a design drawing] on an Apple II computer," he said, grinning. "So here we're driving a \$20,000 pen plotter with a \$700 computer, and the plotter can't keep up."

Scaled Composites' \$2.5-million DARPA contract called for building the AT³ as a proof-of-concept model with all the flying qualities of a full-size prototype. The fixed contract price included 40 flight tests, and it didn't require volumes of advance documentation, interminable reviews by the Pentagon, or safety boards headed by generals.

"They want data, and that's what we deliver," Rutan told me. Payments to Scaled Composites were made only when the program reached certain milestones. That's not the way the Pentagon normally operates, but it's the only way Rutan will do business.

Flying wind-tunnel model

The first 40 flight tests were to be completed by late summer of 1988, with a follow-on series expected to be approved by DARPA. "There was absolutely no wind-tunnel documentation when it made its first flight," Rutan said. "We got right to the flight tests without spending a lot of money." But like all flight-test programs, this one had problems. "The airplane wasn't handling that well on its first tests," Rutan told me. "Directional

stability was weak in low side-slip angle maneuvers [the nose could wander left or right]. So we added tip vanes, or butterflies, to the horizontal stabilizers to fix that.

"On the other hand, some things that we thought were high risk, like the fast-acting flaps, worked very well. Things we thought would be easy, like aileron hinge moments, have been more difficult to work out."

Many of the minor changes happened quickly, Rutan said. For example, his team took advantage of the AT³'s nonmetallic fabrication to rapidly reshape composite edges or to add new pieces of composite material. "Then we sent the pilots back up to evaluate them. Out of fifteen changes, about half were done in less than three hours," Rutan said.

The aileron problem proved more difficult, he noted. When the test pilots reported that they were dissatisfied with the hinge moment—the force it takes to move the ailerons—he called the AT³ in for quick modifications. At one point the team reshaped the lower aileron wing well, extending it by adding fresh composite materials. But time after time, the improvements were not good enough.

Rutan decided that his mistake came in using ailerons sized for the smaller aircraft. With drawings spread out on a table, he and his team sketched a larger aileron, then made a decision on the spot to ground the AT³ for a week until the new pieces could be fabricated and installed.

As flight testing continued, the Defense Department considered running its own tests to determine the AT³'s stealthiness (visibility to radar and other sensors) and its ability to land and takeoff on rugged, unimproved fields.

Cloudy future

For now, however, the AT³ is a plane without a clear future. Whether Rutan's innovative design will lead directly to production, or simply provide data for program planning, has not been determined.

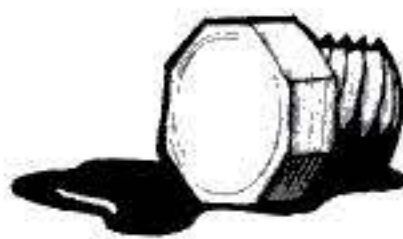
The fate of the 62 percent scale aircraft also must be decided by DARPA. "I'd like to keep it as a 'chase-and-pace' airplane," Rutan told me. "Even though it's one of a kind, its maintenance is very low. And what happens with this kind of aircraft is that you build it stronger than a production model, so its lifetime is essentially unlimited." Then he pointed to the ceiling of his main hangar, where a scaled prototype of the Beech Starship has hung since its flight testing ended.

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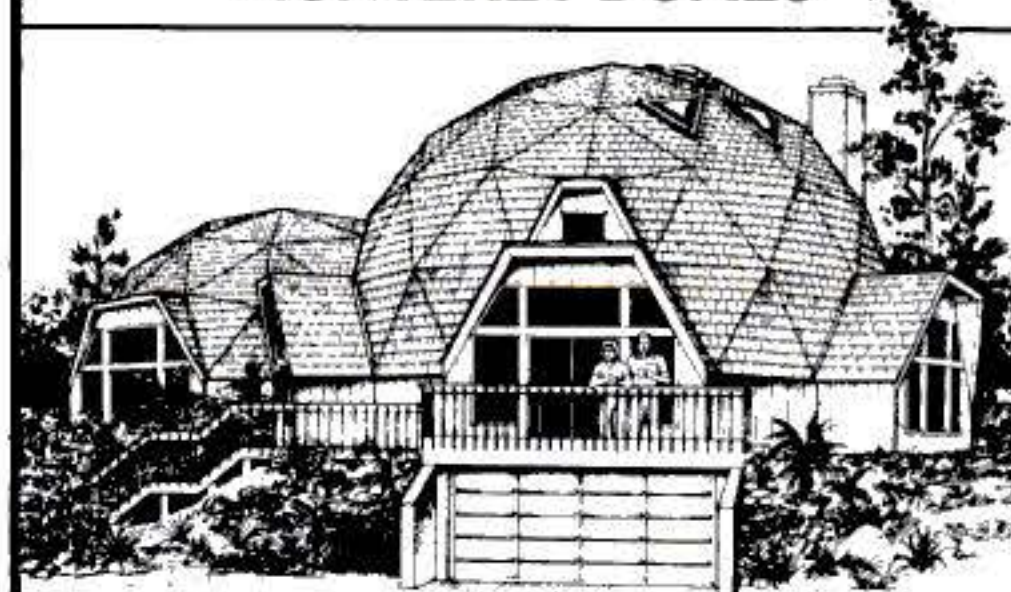
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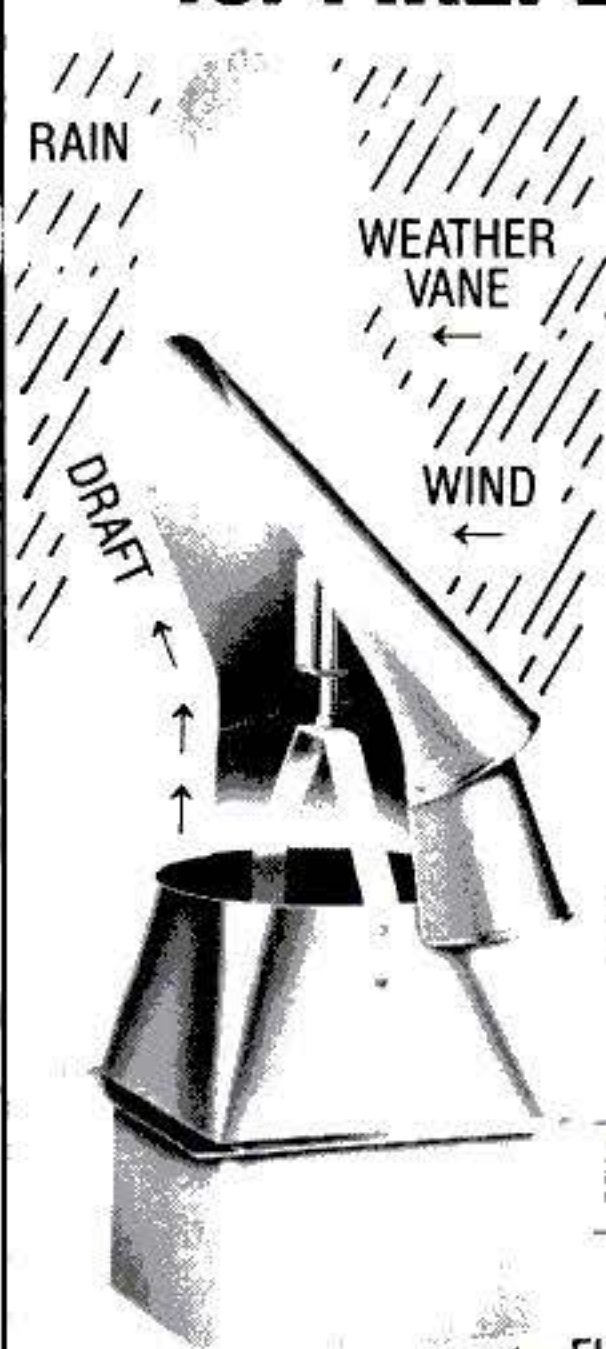
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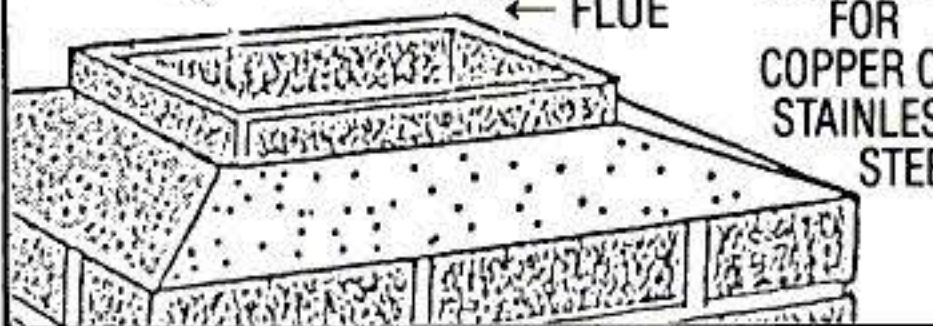
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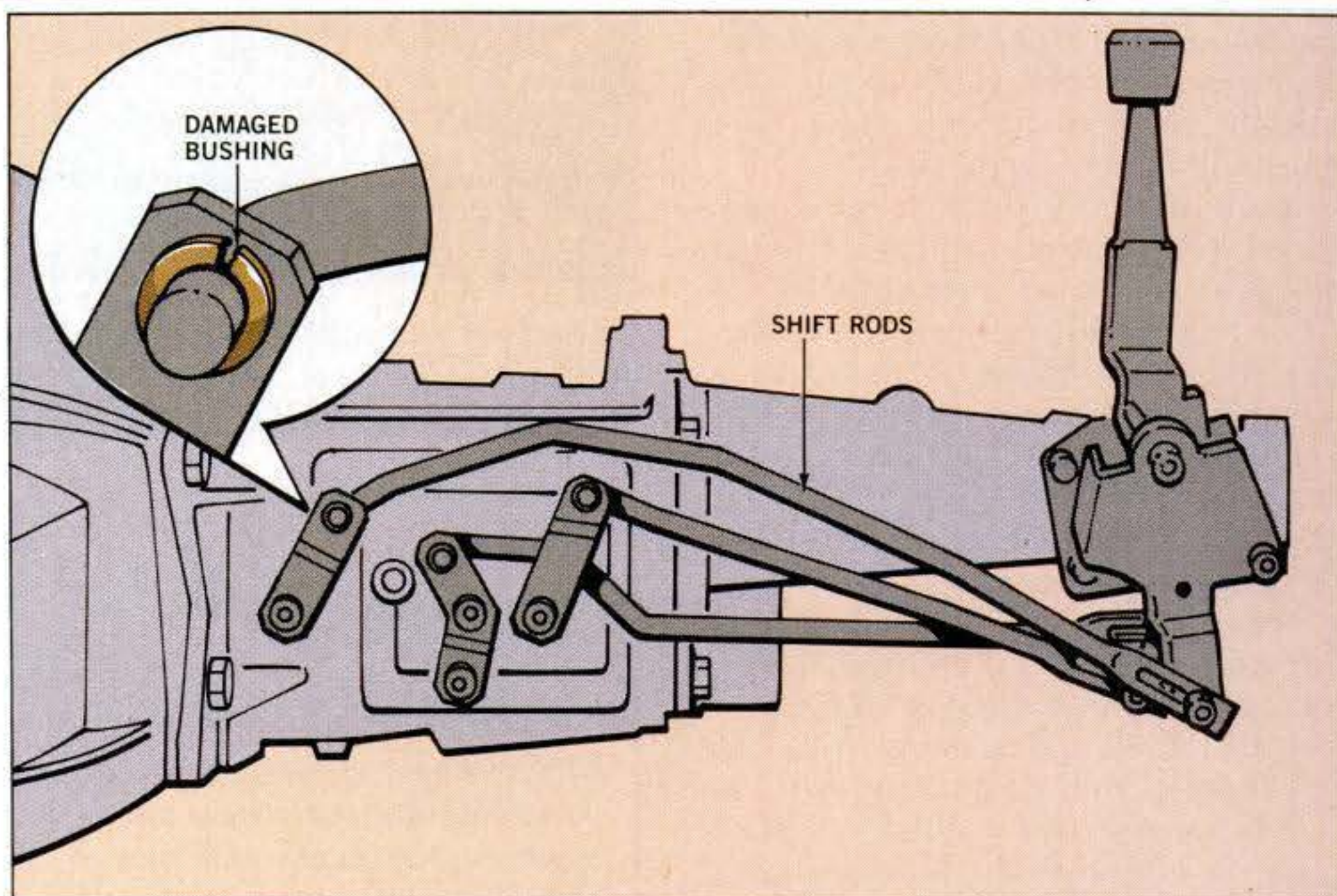
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By **STEVE MERCALDO**

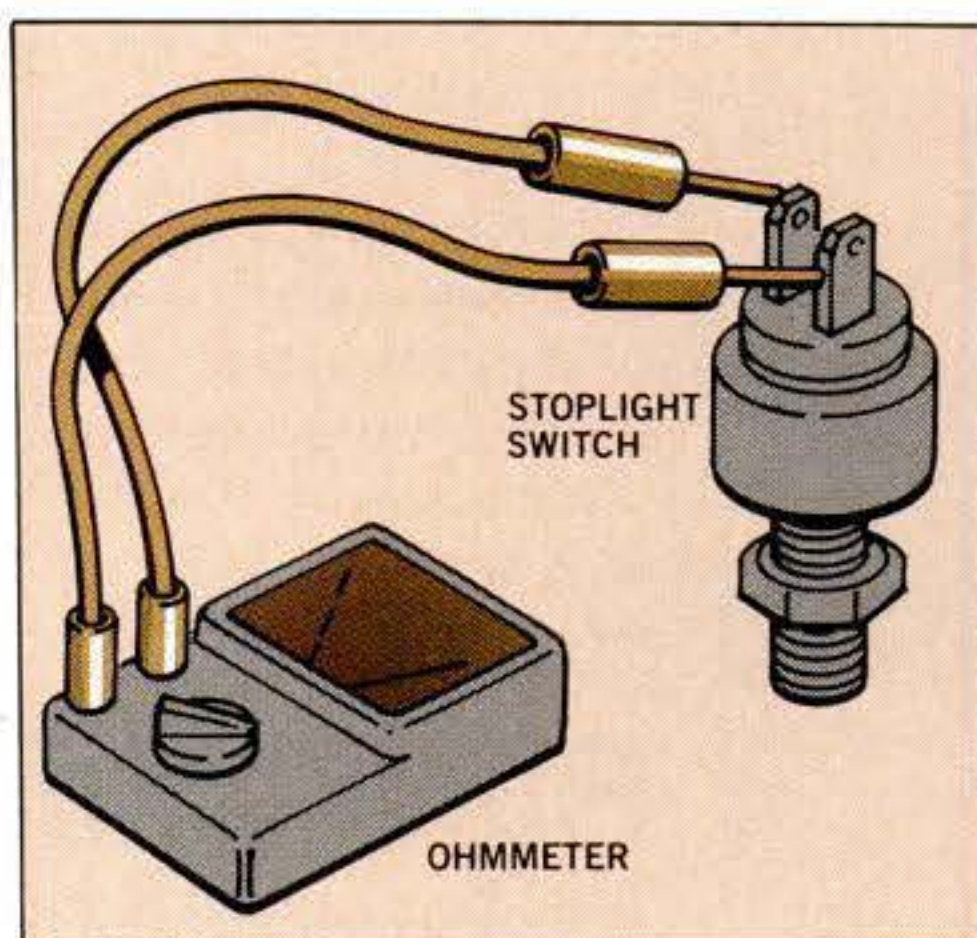
DRAWINGS BY RUSSELL VON SAUERS



Loose, shiftless transmission linkages

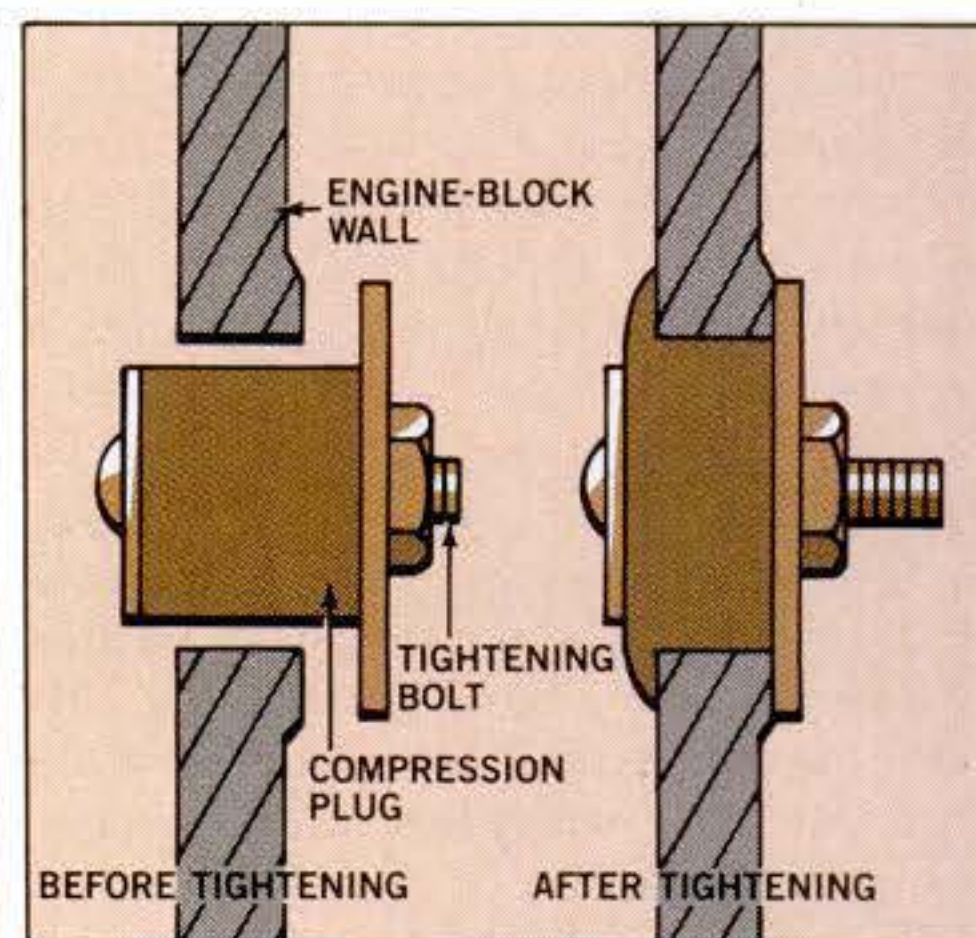
Do you have to hunt for a gear when shifting your manual transmission? Does the transmission jump out of gear when you accelerate? Loose linkages between the shifter and transmission could be the cause of your problems. Check for sloppy linkages by trying to move the shift rods back

and forth. There should be no play between the rods and either the transmission or shifter levers. Connections between the rods and levers should be tight but able to move freely. If there is excessive looseness, check the bushings for signs of wear and damage (see inset) and replace as needed.



Stoplight problems

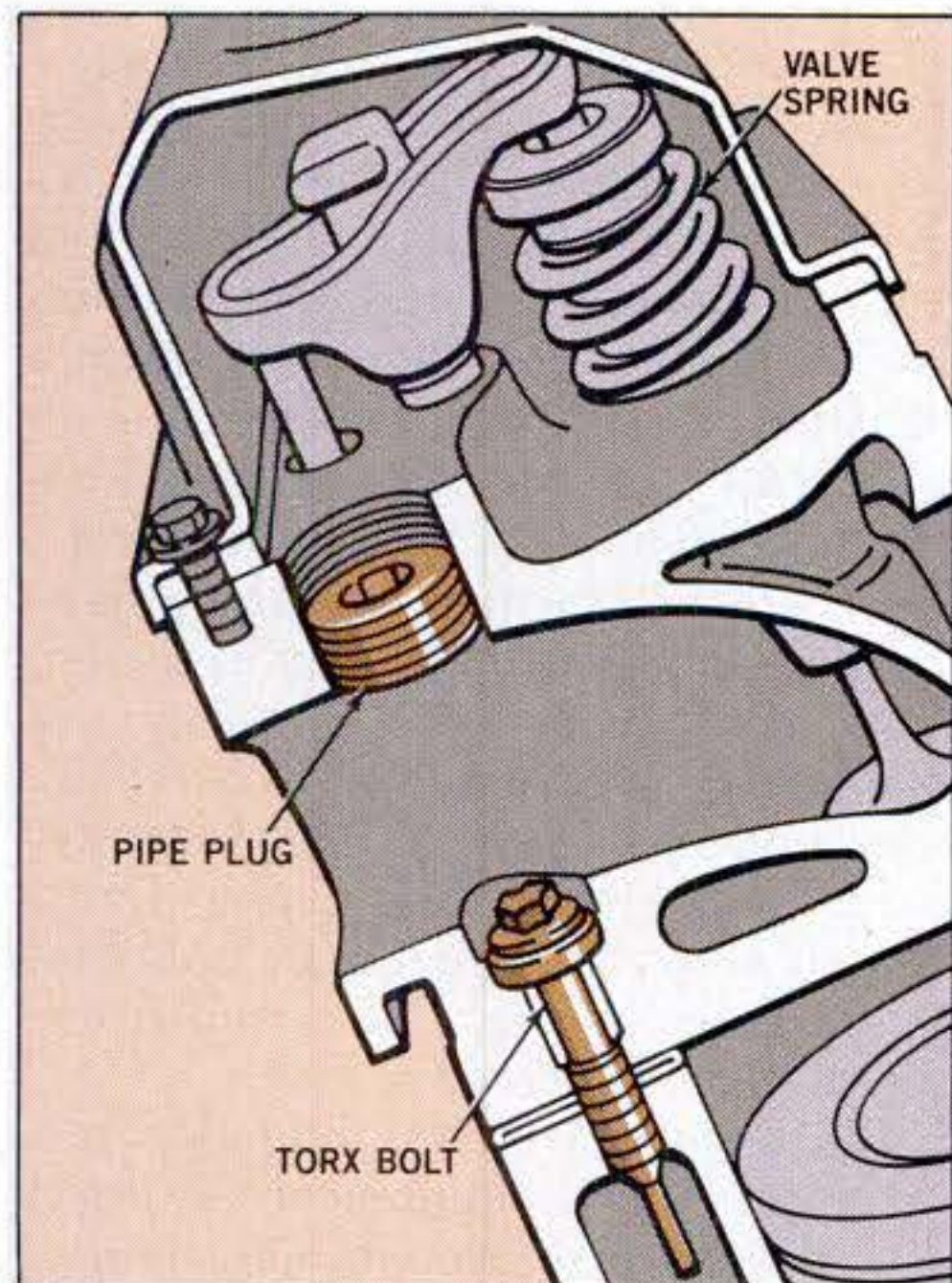
If your stoplights don't work when you step on the brake, test the brake-light switch. Attach the switch's wires to an ohmmeter. With the brake pedal released, there should be an infinite resistance reading, indicating an open circuit. When the pedal is applied, the ohmmeter should read zero, indicating a closed circuit.



Freeze-plug pointers

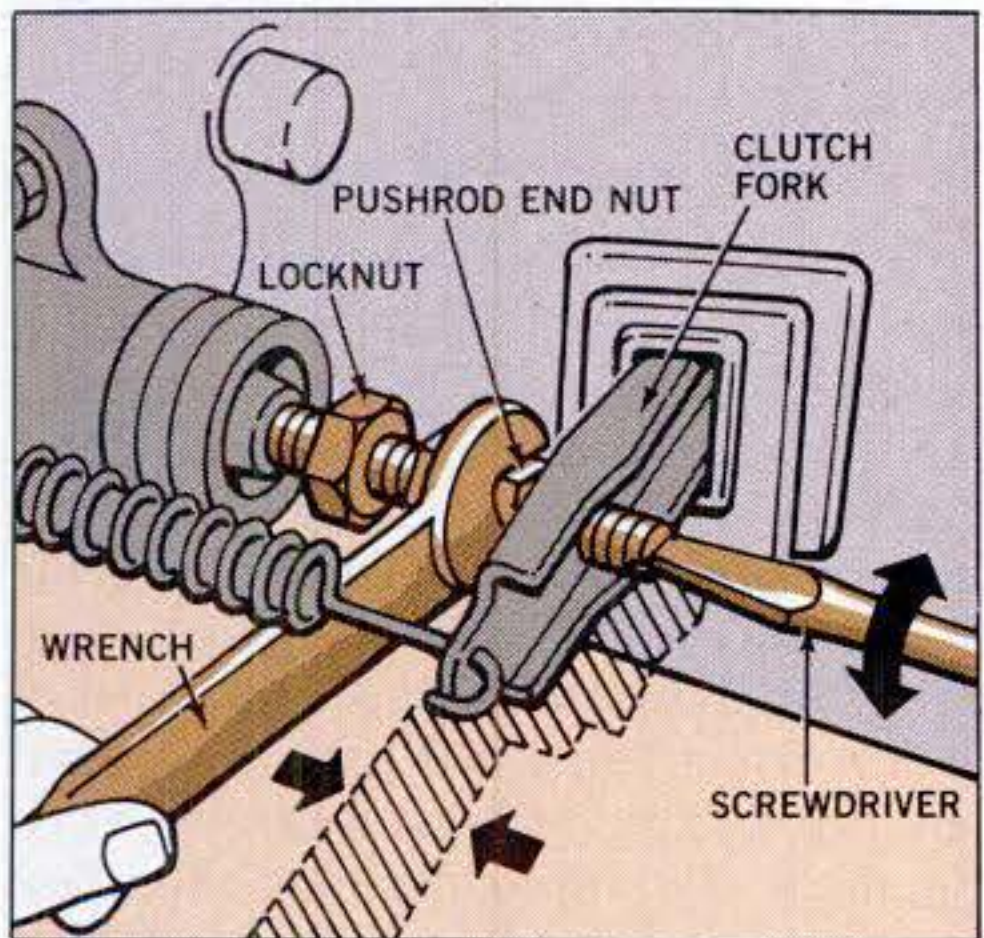
When a freeze plug on an engine block does not fit snugly, coolant can leak. Remove the old plug by hitting it with a hammer and punch; replace with a new plug. If you don't have enough room to swing a hammer and pound the new plug in, use a rubber compression plug, which conforms to the hole after it is tightened.

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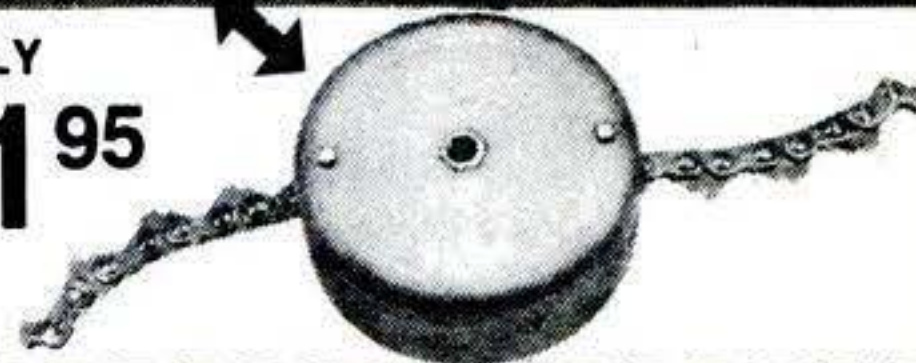
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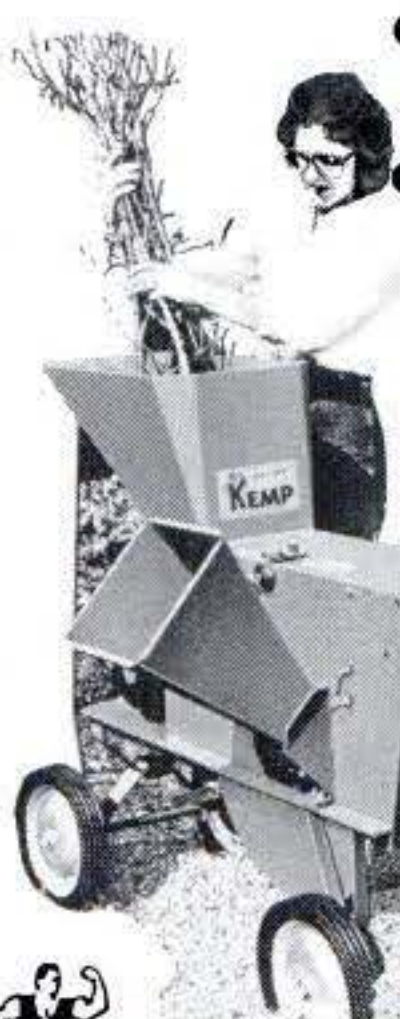
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Missile killers

[Continued from page 50]

That's the hard part. Everyone agrees that hitting an ICBM with an 18-inch smart rock fired from 1,000 miles away will require a variety of technology advances. Many of them are already coming out of development laboratories.

"The engines are a good example," Peller said. "They're smaller and more powerful than ever." Rockwell's Rocketdyne Division has already test-fired both divert engines and attitude-control thrusters for the interceptors. "Fifteen years ago the engine on a Mariner spacecraft weighed 19.4 pounds and had 314 pounds of thrust," he recalled. "The divert engine weighs 1.7 pounds with 400 pounds of thrust. And the attitude-control thruster, with five pounds of thrust, weighs less than four ounces." Much of the improvement comes from using new lightweight alloys and other materials that didn't exist in the 1970s, and from more-efficient designs.

Electronics are changing fast too. "Our guidance computer for the flight test does two million calculations a second, but weighs only about one pound," Peller said. "That will be down to half a pound for an operational system that will be faster."

Divert engines themselves constitute a new technology. The engines are fixed in place and can't be swiveled or gimbaled. This makes them simpler. Then how can they make course corrections that may measure a fraction of a degree? Attitude-control thrusters reposition the entire vehicle before the divert engines fire. It all happens quickly.

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Making the whole system work together is forcing other advances in software. Experts from Logicon, Inc., developed a battle-management scenario for Rockwell that solved the potential problem of separate platforms firing interceptors at the same missile. "Each platform will have a set of calculations that looks at the global picture, assigns values to targets, then sends its own interceptors to the highest values," said Logicon's project manager, Allen Atkinson. "There's an element of autonomy, but you still have complete coordination." If any platform is destroyed by an anti-satellite weapon, the others record a lost communications link and expand their own coverage to fill the gap.

Once it leaves the platform each interceptor will get updates on its target's location. But its own computer will calculate trajectories and course changes. "The interceptor's range of target acquisition should be some-

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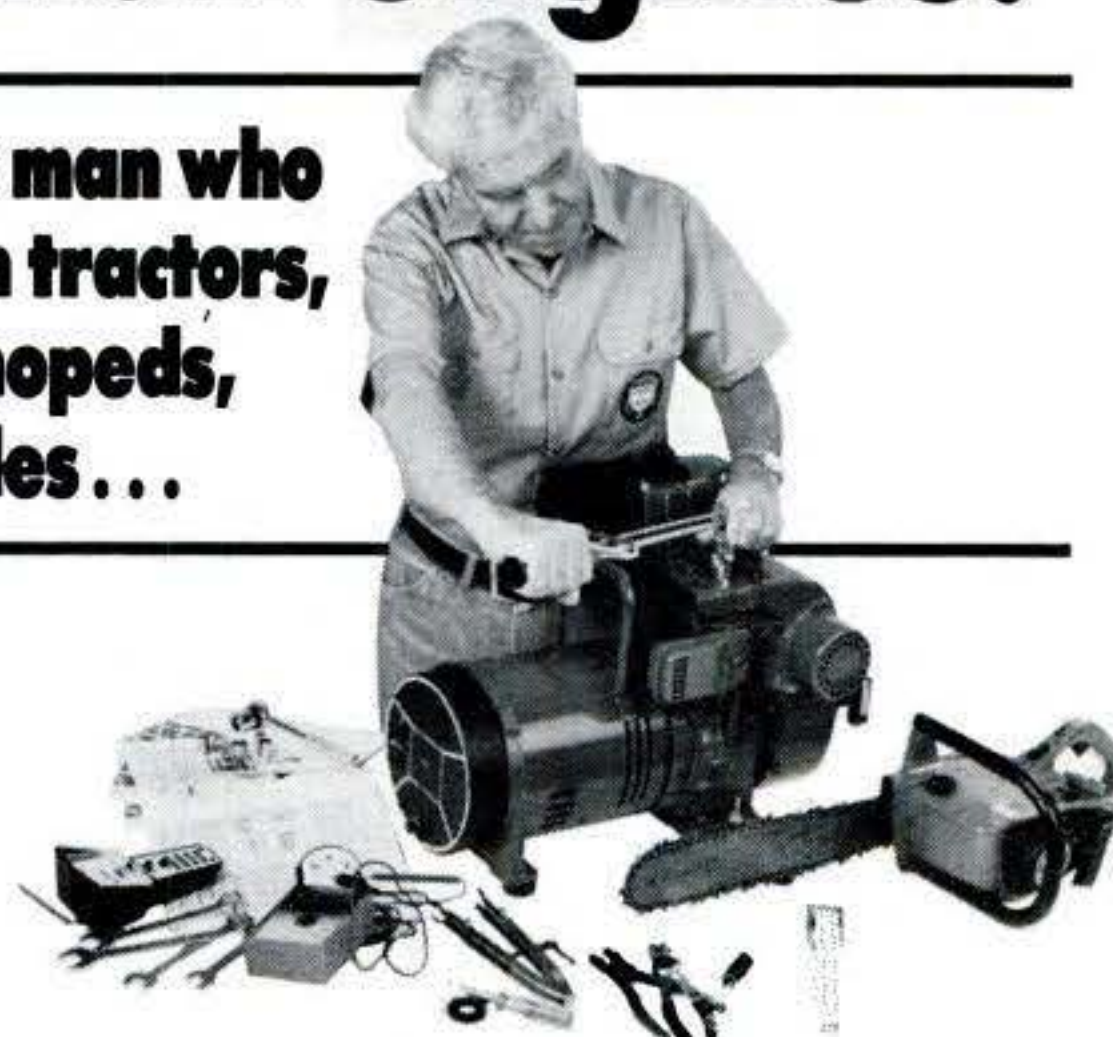
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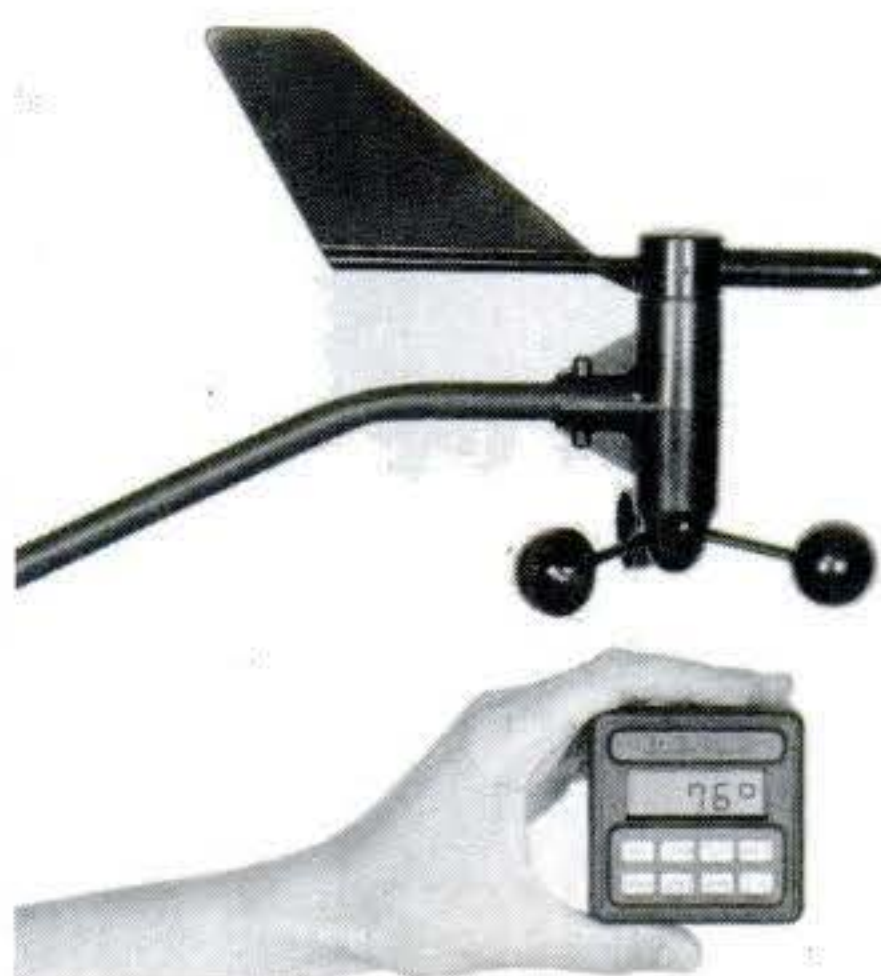
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Missile killers

Continued

where between fifty and two hundred miles," VandeKoppel explained. "After that, it's completely on its own."

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"That's one of the primary breakthroughs that makes a space-based interceptor possible," said VandeKoppel. "We actually develop images on board. First we get the ICBM plume, and then, as it comes into view, the hard body." The processing is handled by a tiny computer called a GAP-based image processor (for geometric arithmetic parallel), which handles 80 billion calculations per second.

Despite all the new hardware and software, program critics remain unconvinced that any system will be good enough to intercept an ICBM. At present the program's primary focus is on catching a liquid-fueled Soviet rocket during its first five minutes of boost. "By the time you have such a thing," IBM's Garwin said, "it can be defeated by the Soviets going to solid-fueled rockets with shorter burn times."

Such ICBMs already exist in the Soviet inventory. They accelerate faster than liquid-fueled rockets and burn out after about three minutes. Catching them will be harder, Rockwell and Martin Marietta officials told me, but not impossible. Calculating counter-measures and being ready to handle whatever the Soviets might have is an integral part of the job, they say.

The debate will continue

With the interceptor program less than two years old, both contractors are confident that it will work. But the Congressional Office of Technology Assessment is equally confident that the program will be unable to guarantee protection against missile attack. In a recently released study, it concluded that the system's complex computer programs would be dangerously failure prone in a nuclear war.

The final form of this immensely complex project may not emerge for a number of years. Even if the administration and Congress give SDI's first phase the go-ahead, it looks as if the original goal of having intercept platforms in orbit by the middle of the next decade is receding toward the millennium. And in the intervening years many technical, budgetary, and diplomatic debates will take place that will affect the outcome.

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The odd couple

[Continued from page 57]

gleaned from the cameras positioned atop and one-third of the way down the mast is compared against the computer's version of optimum depth, draft, position, and twist of the sails at a given wind speed and angle to the wind. "The computers and the crew do interact," says Talbot Wilson, "but because of the boat's size the crew will probably have to wear radio headphones to make sure they hear instructions." To power this computer system the *New Zealand* will have the distinction of being the first America's Cup boat to carry three on-board generators.

Defender's response

Faced with a boat that Dennis Conner has deemed a "monster," Sail America decided to build not a match but a radically different boat that could virtually guarantee a win. After all, the city of San Diego stands to lose up to \$1 billion if the 1991 America's Cup—normally a multinational event—is moved to Auckland, New Zealand.

"After the judge ruled that the challenge was valid [in November 1987], the first hurried design meeting took place in a conference room at the Marine Air Terminal of New York's La Guardia Airport," recalls John Marshall, head of the design team. Included were hydrodynamicists, aerodynamic experts, previous America's Cup designers, as well as multi-hull designers and sailors. "We depended on the same computer velocity prediction program ["Techno-Yachts," Feb. '87] that was used extensively for the twelve-meters," says Marshall of the search for the right boat. "But for this project we expanded them to have the capability of dealing with hydrofoils, multi-hulls, and a variety of mono-hull configurations."

David Hubbard, a member of the design team, and considered the father of the rigid wing sail, says the main design consideration was "the very, very short time we had to produce a boat." The results of the VPPs combined with these time constraints pointed to a catamaran as the boat of choice.

The next decision was the length of the defender. The best-known racing catamaran is the Formula 40, a light, fast 40-footer that is popular in European racing events. But the VPP analysis showed that length was important for straight-line speed, an important consideration for the America's Cup course, which includes an upwind and a downwind leg. A 90-foot catamaran is technologically possible, but difficult to control and optimize.

The design team decided on a 60-foot cat with thin (4½ feet at the bow)

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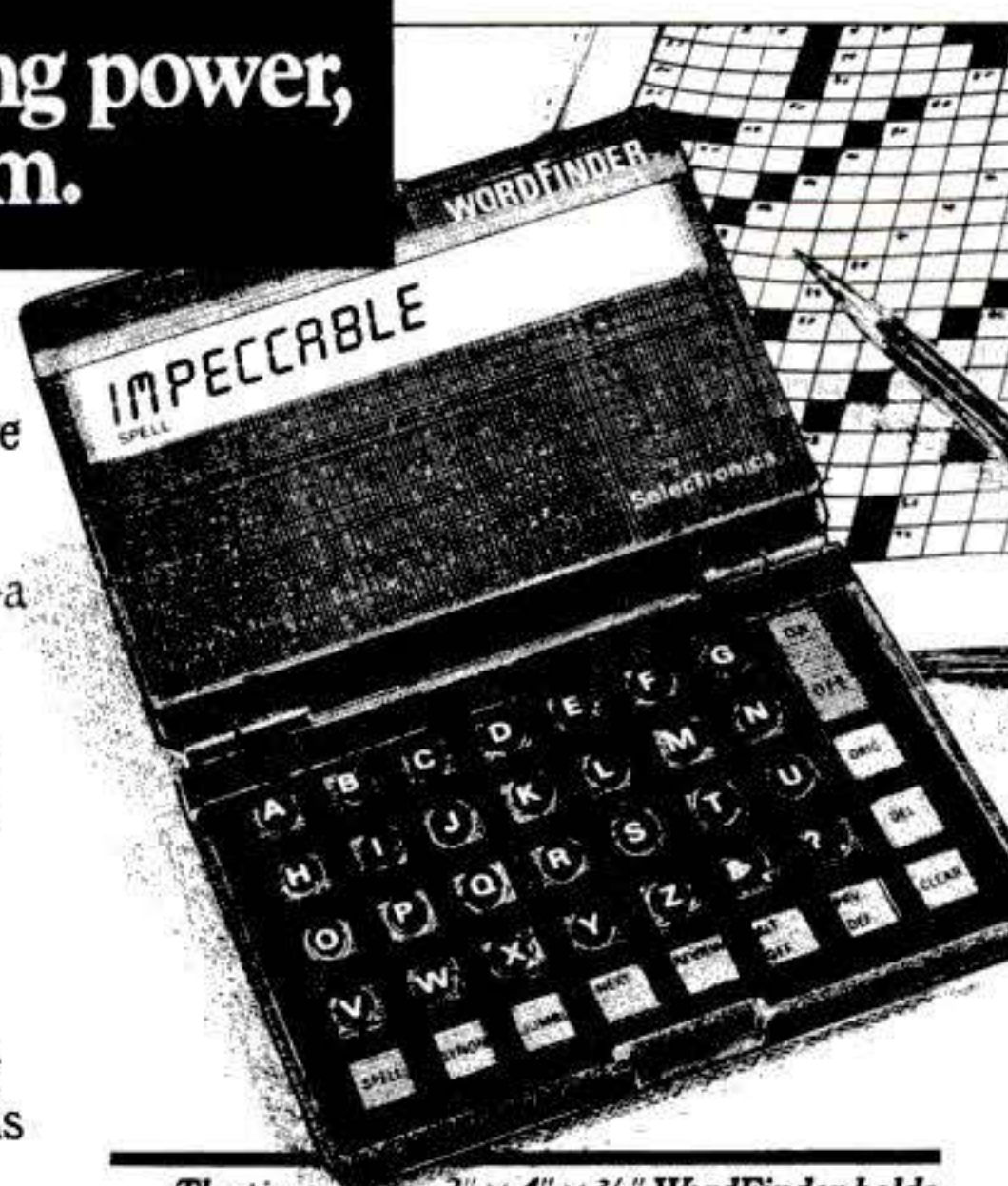
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hulls and a revolutionary semi-rigid wing sail. The design team decided to develop a hard wing sail because of its inherent aerodynamic efficiency as compared with a soft rig. A sail is not just a parachute billowing out in the wind, rather its shape and rigid battens form an airfoil for the wind to blow past and generate lift. But soft sails—even those made of materials like Kevlar aramid fiber and Mylar plastic film—stretch and distort, creating eddies and vortices that reduce the lift coefficient. Also, the discontinuous mast that holds the soft sail disturbs airflow.

The shape of a rigid wing is continuous and can be controlled more precisely, both from top to bottom and across the airfoil. And using airflow re-energizing techniques standard for airplane wings to reduce turbulence, airflow remains attached along the wing, and the lift coefficient approaches its maximum. Marshall, who is also chief operating officer of Henry R. Hinckley Co., a yacht design and production firm, describes the final outcome: "This boat is sort of a minimalist solution. The idea is to use the least weight—the smallest boat that can be sailed by the smallest number of people with the most efficiency." The cat will probably carry only a five-man crew; and Conner, the hefty skipper, is even on a strict weight-loss plan. Marshall adds: "The *New Zealand* is a relatively bigger brute-force sort of boat. They have the luxury of putting stuff on their boat that I wouldn't dream of putting on ours."

Winging it

Six months after the *Stars and Stripes* design team first met at La Guardia to answer the *New Zealand's* challenge, I arrived in San Diego to witness the final product. It was the night before the official press briefing, and I strolled down to the dockside compound where the boat was being assembled. The hulls were covered with brown paper, and the gleaming white wing sail lay horizontally on supports. It was after 6 p.m., and the crew had about 14 hours before curtain, but Duncan MacLane, one of the wing-sail designers, was not hurrying. He lay on a cloth-covered board, suspended over the partially assembled wing by a small crane. He screwed the aramid-fiber-covered segments of the wing sail's trailing edge to the fixed portion of the wing. Hubbard stood by, watching the growth of his baby, a 90-foot carbon-fiber airfoil. "It's going to be a long night," he commented.

The wing sail is not a new concept. Hubbard has been designing rigid

Continued

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The odd couple *Continued*

sails for a series of Little America's Cup boats called *Patient Lady* since 1971 [Feb. '72, Aug. '74]. The wing sail Hubbard and MacLane designed for the *Stars and Stripes* catamaran was their sixth and most advanced version to date. It consists of three elements: 1) a rigid front molded section attached to a series of plastic-film-covered carbon ribs; 2) a flap section that forms a closed joint with element one and acts as a pivot for element three; and 3) a series of six carbon-reinforced "soft" aramid-fiber panels.

Lying on its side at the boat compound, the wing sail looked decidedly aeronautical. "It's not quite the same thing as an airplane, which generally flies in one direction," says Hubbard. "This one has to fly in two," he adds, noting that the wing has to function on two tacks. John Roncz, a renowned airfoil expert who designed the wings for *Voyager's* round-the-world flight ["Rutan's Ultimate Flyer," Sept. '84], used his advanced computer models to change the shape of the *Patient Lady* wing-sail elements to provide

more lift for the larger cat. The wing sail was actually constructed in an airplane hangar by *Voyager* builder Burt Rutan at his Mojave, Calif., company, Scaled Composites. "The design of a wing-sail rig like this is much more difficult than the airplane wing," says Rutan. "From what I've seen, I don't know how evolution ever allowed people to sail before they flew."

The same principles that apply to an airplane wing stand true for the wing sail: cambering, or curving, the wing accelerates airflow, creating a low-pressure bubble over the wing and thus generating lift. And like an airplane wing, as air flows back across the foil, it faces an adverse pressure gradient and wants to break away from the wing. This unattached flow is the initiation of stalling in an airplane: It means lost power in a catamaran. To solve this problem the wing-sail flap (element 2) is deflected to let air flow up from the underside of the wing sail. This new airflow entrains the breakaway flow, redirecting it along the wing's surface and developing a new bubble of low pressure farther back on the wing. Lift is thus maintained along the wing's length.

I visited Hubbard in his trailer at the *Stars and Stripes* compound to find out more about the wing sail. "Have a seat," he said politely, gesturing to the less than plushly carpeted trailer floor. The furniture had not arrived yet. Lean, tan, and sporting a crop of wiry gray-black hair, Hubbard looked the part of yacht racer/designer as he sat on the floor with his knees pulled up to his chest. He brought a wooden model down from the window ledge and explained how the crew would operate the wing. "There are really only three basic controls once underway," he said. "The first control, the main sheet, moves the whole wing back and forth laterally. Another line gives you the camber, or angle of attack. And the final control device gives you the twist profile of the wing."

This twist control is an important feature for the catamaran. Hubbard explained why: "In a sailboat, as you go up from the water the wind velocity changes rapidly. The wind speed is lower at the bottom of the sail than at the top because of friction caused by the water." To get the optimum power from the wind, the wing sail is set at a different angle to the wind at the top than at the bottom using the twist profile control.

A second *Stars and Stripes* catamaran is outfitted with a traditional soft-sail rig. In trial runs the wing sail proved faster upwind; because it has more sail area, the soft rig is the choice for downwind sailing. Marshall

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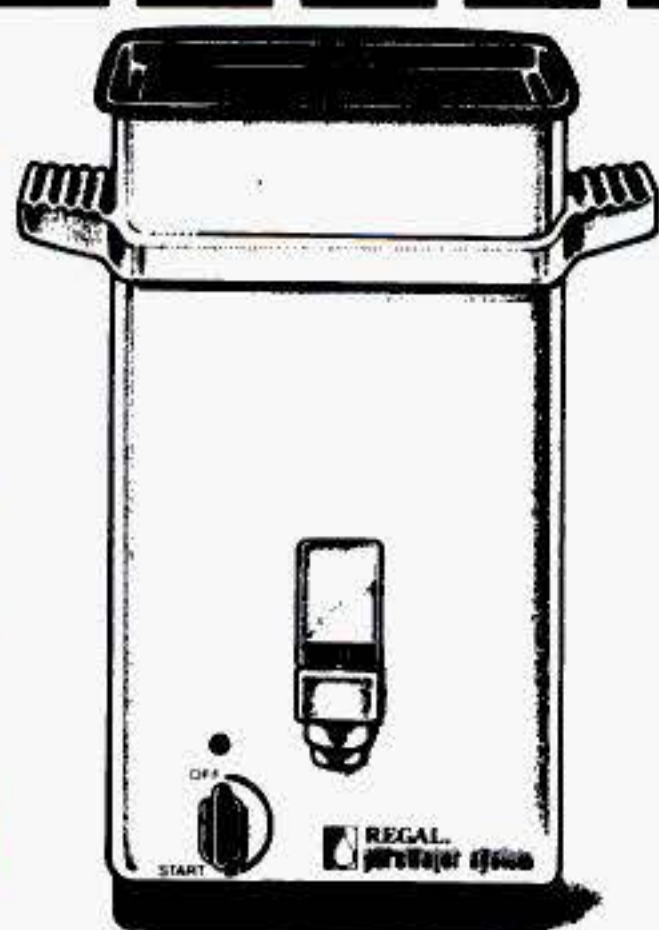
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says that for downwind sailing a geniker, an asymmetrical head sail, will be added to the hard rig.

What would a race between New Zealand's *Big Boat* and the *Stars and Stripes* cat be like? "It's no match at all," says Graeme Colman, the media liaison for the New Zealand Challenge. Dennis Conner does not agree: "Most of the people who say this is a mismatch really don't know what they're talking about." He mentions the unpredictable nature of the practice catamarans—modified Formula 40s—and the need for constant crew alertness. "I've been upside down in the catamarans fifty percent of the time I've been sailing in the last week, so I'm not so confident that I can even get around the race course at this point."

Both boats are designed for September conditions off the southern end of San Diego called Point Loma, where winds average about 10 knots. But a drop or increase in wind speed could be a deciding factor in this unlikely race. The reason: *New Zealand* is at its best in light winds, below 10 knots, because of its light hull and huge sail area. The catamaran, on the other hand, is more efficient in winds above 10 knots—as long as the sea isn't too rough. With a light wind it is more difficult to "fly a hull." And two hulls in the water means more wetted sur-

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On July 17, 1987, New Zealand shipping magnate Michael Fay invited the commodore and vice commodore of the San Diego Yacht Club to lunch and handed them quite a mouthful. Five months had passed since the SDYC had won the Cup in Australia, and no challenge specifics had been announced. Fay, using a literal reading of the Deed of Gift, presented the officers with a challenge of his own: a June 1988 race date in San Diego rather than the standard four-year wait—and 90-foot mono-hulls instead of traditional 12-meters.

The SDYC ignored the challenge until November 25th, when New York State Supreme Court Judge Carmen Beauchamp Ciparick ruled in Fay's favor, upholding the challenge. Because of the court delay, the race date was moved to Sept. 19, 1988.

From then on Fay and Sail America, the syndicate chosen to defend the Cup, have fought bitterly about race location. Because the *New Zealand* was designed for the light winds off San Diego, Sail America decided to move the race to Long Beach, Calif., or Hawaii, where winds are stronger. Fay wanted a multinational event in 90-footers; Sail America wanted a one-on-one race. Finally, Sail America announced it would build a multi-hull.

Fay's young lawyer, Andrew Johns, filed court papers on May 5th that seek to force the SDYC to defend with a 90-foot-waterline mono-hull of the same dimensions and type as the *New Zealand*. By our press date no decision had been made. If the judge rules in Fay's favor, he has offered to postpone the match until June of 1989 to give the SDYC time to build a mono-hull. If the club fails to do so, it would have to forfeit the Cup. But if the judge rules in favor of the catamaran there could either be a historic race or *New Zealand* might hoist a protest flag and go back to court.—N. F.

face drag. In rough waters the hulls sit in different patterns of waves, and the boat is thrown around more.

Even with all the time and millions of dollars poured into this recent challenge, the catamaran and the *Big Boat* might never meet at the starting line. Is all this hullabaloo good for the America's Cup? Marshall says, "I think the burst of technology has been fan-

tastic. We've been using twelve-meters since 1958, and we're probably ready for a new class." Not surprisingly, Bowler thinks the *New Zealand* design is a good choice for the new class. "There'd be nothing more thrilling than to watch five of these boats coming up to the start line all together," he says. "This one desperately needs a mate." PS

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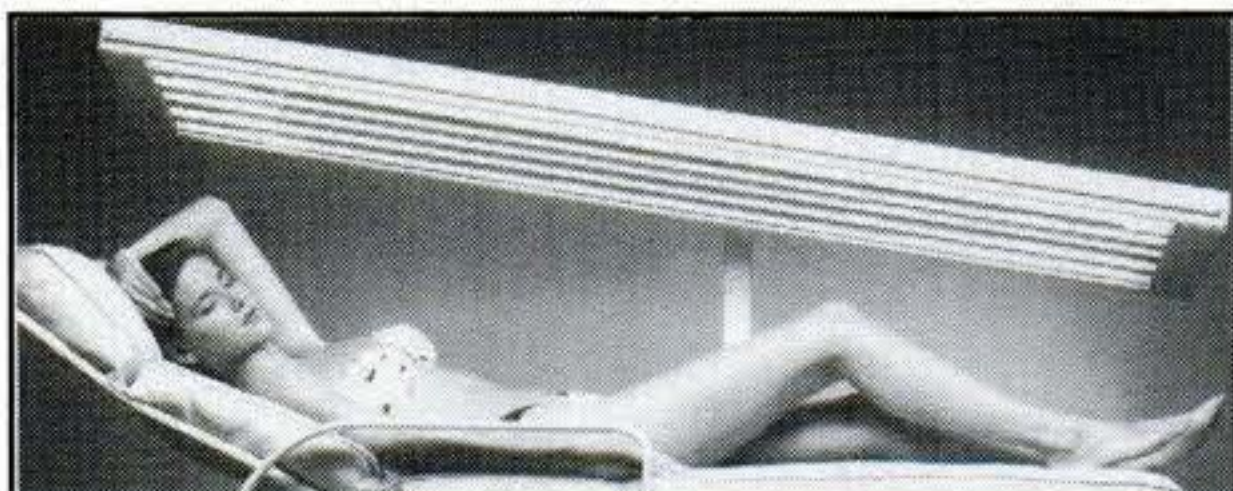
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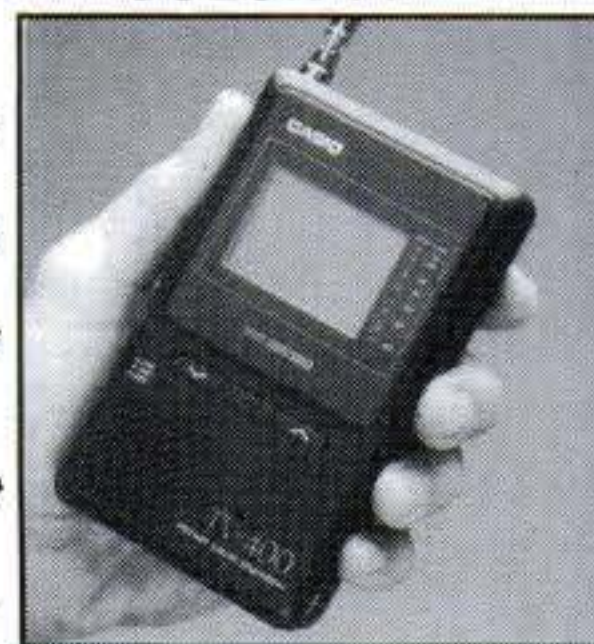
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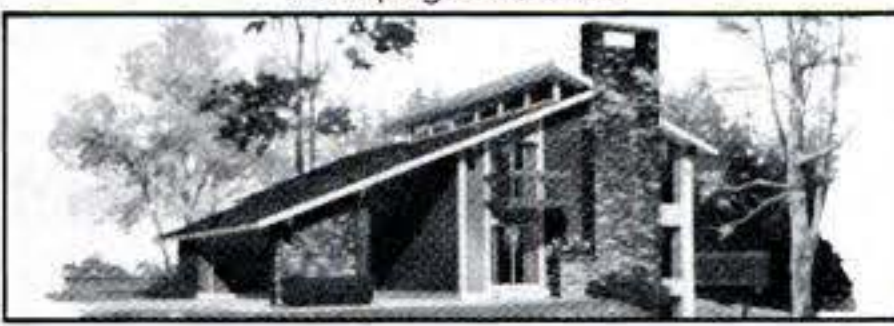
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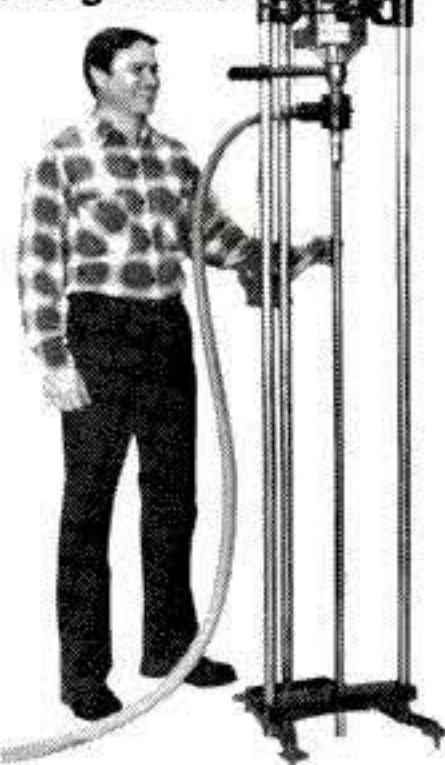
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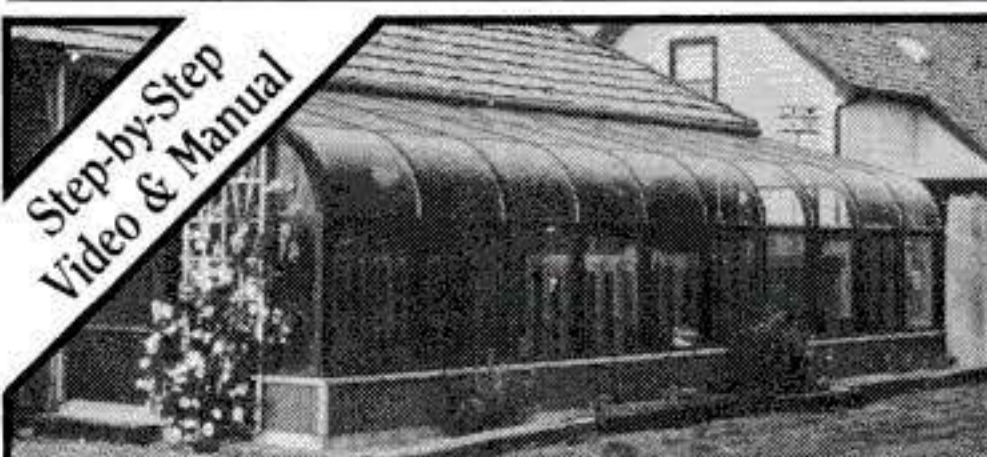
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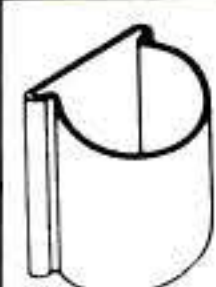


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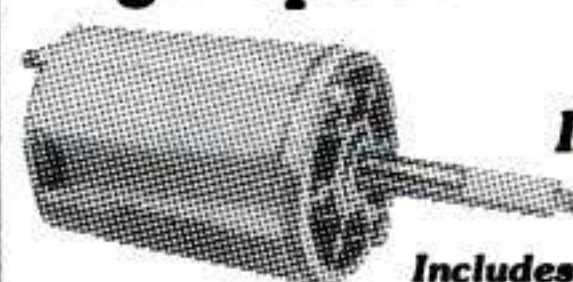
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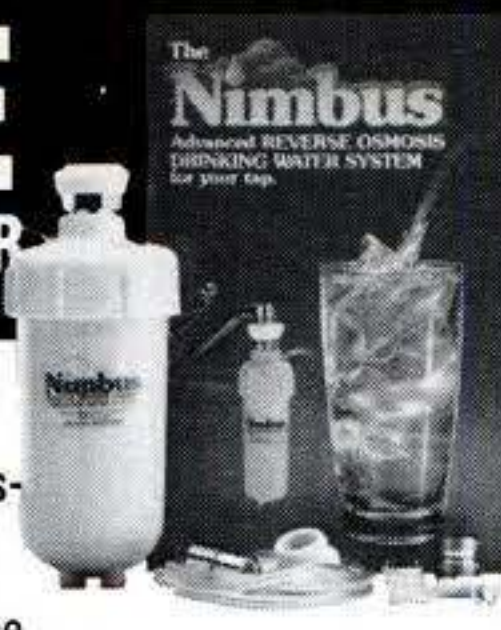
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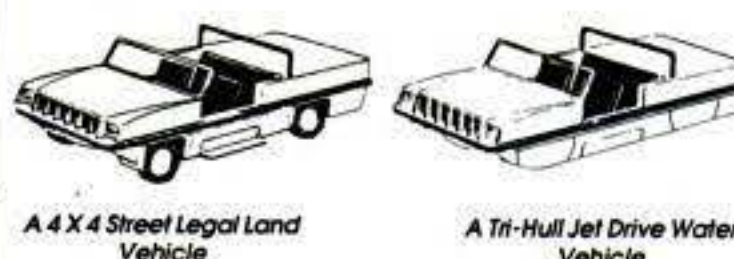
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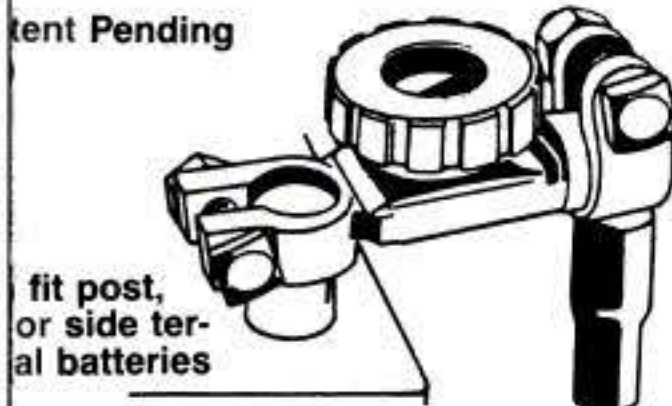
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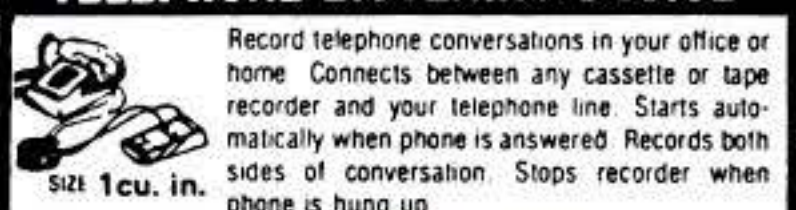
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We recently learned of Murry Broach, a 48 year old ex-factory worker. Murry started a very suc-cessful business in his home, with practically NO INVESTMENT.

The real beauty of his situation is his product. He gets it FREE!

Murry spends a few pennies "converting" the product to an in-demand item, then markets it by the thousands. "It's easy," he says, "and anyone can do it." No per-sonal selling is involved.

The lines in his face - the grey beard and hair, testify to over twenty years "at hard labor" in a paper mill. He became disabled in 1983 and was forced to look for an easier way to make a living. After discovering the FREE product, it was all "clear sailing."

Murry showed us last year's bank deposits of just over \$242,456. He says he hasn't de-



Murry Broach

cided yet just where to stop increasing his in-come! He admits how-ever, at some point, he'd have to move the busi-ness off his dining room table.

When asked, "what is the product you can get FREE," Broach answers with a smile. "That," he

says, "would be like telling you the ending of a movie before you've seen it!"

He's quick to add - "it's nothing illegal or immoral. It's NOT food, water, religion, mind power or hard work. NOTHING to do with sex, multi-level marketing, chain letter schemes, envelope stuffing, real estate, computers or precious metals."

"In fact," he tells you, "it's some-thing I know YOU need right now! It is definitely in-demand. It's NOT a gimmick of any kind and practi-cally anyone will buy it!"

Want to learn how YOU could become successful and independ-ent from a product you can get FREE? Murry has offered to send complete details to readers of this column.

Just print your name and address on a piece of paper and send to "FREE" Dept. M602 - 708 - 12th Street N.W.-Canton, Ohio 44703.

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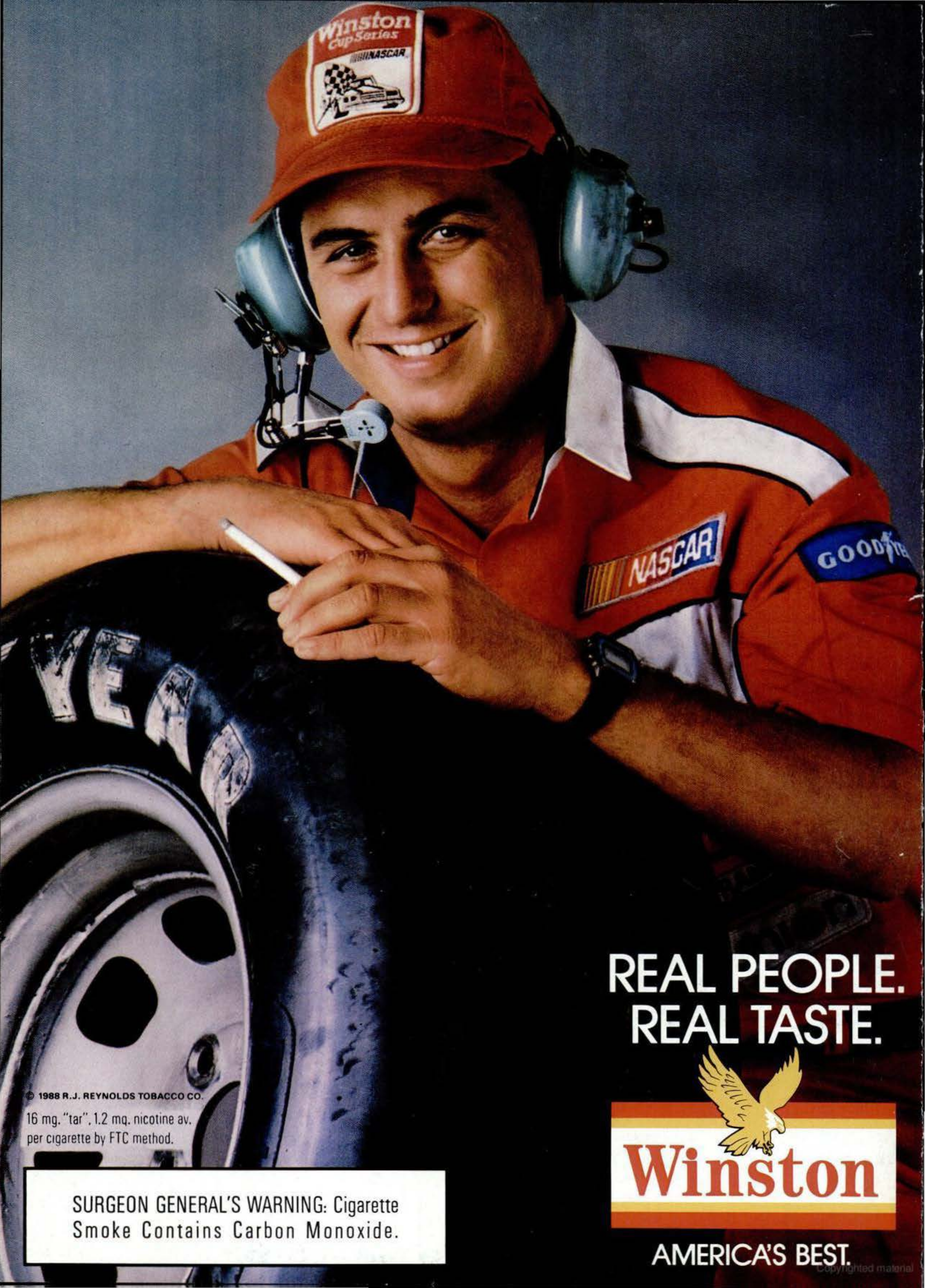
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